DOCUMENT RESUME

ED 254 656 CE 040 860

AUTHOR	Laster, Janet F.
TITLE	Toward Excellence in Secondary Vocational Education: Using Cognitive Psychology in Curriculum Planning. Information Series No. 297.
INSTITUTION	Ohio State Univ., Columbus. National Center for Research in Vocational Education.
SPONS AGENCY	Office of Vocational and Adult Education (ED), Washington, DC.
PUB DATE	85
CONTRACT	300-83-0016
NOTE	75p.; For related documents, see CE 040 854-856 and CE 040 858-859.
AVAILABLE FROM	National Center Publications, Box F, National Center for Research in Vocational Education, 1960 Kenny Road, Columbus, OH 43210-1090 (IN297--$7.25).
PUB TYPE	Information Analyses (070)
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	Cognitive Development; *Cognitive Processes; Cognitive Style; *Curriculum Development; *Epistemology; Learning; Learning Processes; *Problem Solving; Secondary Education; Skill Development; *Vocational Education
IDENTIFIERS	*Cognitive Psychology; Excellence in Education; Self Monitoring

ABSTRACT

Written for curriculum developers and vocational education instructors, this publication provides an understanding of cognitive concepts and methods using an information processing paradigm and shows how to apply this knowledge in development of curriculum and instructional plans. Chapter 1 reviews needs and characteristics of vocational education students and the objectives of vocational education to which cognitive psychology is applicable. Chapter 2 examines recent advances in cognitive psychology--the new concepts and research methods being introduced--that may be helpful to vocational educators. Chapter 3 suggests implications for what and how instructors should teach in vocational education, including expansion of content to include problem-solving, self-monitoring, and learning skills; teaching of an integrated knowledge structure; and development of critical problem-solving, self-monitoring, and learning skills by students. The chapter concludes with specific suggestions curriculum planners can use. Chapter 4 summarizes the advances and implications for curriculum and instruction and draws conclusions for helping students develop problem-solving and learning skills. Recommendations are proposed for applying cognitive psychology concepts to vocational education. These include development of a problem-solving and learning component, implementation of an information processing approach to learning, and incorporation of practice opportunities for problem solving. (YLB)

ED254656

Information Series No. 297

TOWARD EXCELLENCE IN SECONDARY VOCATIONAL EDUCATION: USING COGNITIVE PSYCHOLOGY IN CURRICULUM PLANNING

Janet F. Laster
The Ohio State University

The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road
Columbus, Ohio 43210-1090

1985

CE040860

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☒ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

THE NATIONAL CENTER MISSION STATEMENT

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Providing information for national planning and policy
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

For further information contact:

Program Information Office
National Center for Research
in Vocational Education
The Ohio State University
1960 Kenny Road
Columbus, Ohio 43210-1090

Telephone: (614) 486-3655 or (800) 848-4815
Cable: CTVOCEDOSU/Columbus, Ohio
Telex: 8104821894

FUNDING INFORMATION

Project Title:	National Center for Research in Vocational Education, Applied Research and Development
Contract Number:	300830016
Project Number:	051OC40060/051OC40061
Act Under Which Funds Administered:	Education Amendments of 1976, P.L. 94-482
Source of Contract:	Office of Vocational and Adult Education U.S. Department of Education Washington, D.C. 20202
Contractor:	The National Center for Research in Vocational Education The Ohio State University Columbus, Ohio 43210-1090
Executive Director:	Robert E. Taylor
Disclaimer:	This publication was prepared pursuant to a contract with the Office of Vocational and Adult Education, U.S. Department of Education. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their judgment in professional and technical matters. Points of view or opinions do not, therefore, necessarily represent official U.S. Department of Education position or policy.
Discrimination Prohibited:	Title VI of the Civil Rights Act of 1964 states: "No person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance." Title IX of the Education Amendments of 1972 states: "No person in the United States shall, on the basis of sex, be excluded from participation in, or be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance." Therefore, the National Center for Research in Vocational Education Project, like every program or activity receiving financial assistance from the U.S. Department of Education, must be operated in compliance with these laws.

CONTENTS

TABLES AND FIGURES v

FOREWORD vii

PREFACE ix

EXECUTIVE SUMMARY xi

INTRODUCTION 1

- Changing Workplace 1
- Needs of Vocational Education Students 1
- Curriculum Development and Cognitive Psychology 2

ADVANCES IN COGNITIVE PSYCHOLOGY: A BASIS FOR CURRICULUM AND INSTRUCTION DECISIONS 3

- Cognition: An Intervening Information Processing/Controlling System 3
- Cognitive Components of Competent, Intelligent Problem-solving Performance 11
- Intelligence: Modifiable Thinking and Learning Skills 17
- Learning: Constructive, Adaptive Action 18
- Learners: Controllers of Learning Behavior 19
- Cognitive Task Analysis Tools 21

IMPLICATIONS FOR CURRICULUM AND INSTRUCTION IN VOCATIONAL EDUCATION 27

- What to Teach: An Integrated Knowledge Base and Thinking and Learning Processes 27
- How to Teach: Instructional Strategies 33
- Suggestions for Curriculum Planners 38

PROBLEM-SOLVING AND LEARNING SKILLS IN VOCATIONAL EDUCATION 41

- Summary of Advances in Cognitive Psychology 41
- Implications for Curriculum and Instruction 42
- Conclusions 42
- Recommendations for Vocational Education 44

REFERENCES AND RELATED READINGS 49

TABLES AND FIGURES

Table

1. EXAMPLES OF COGNITIVE STRATEGIES AND PROCESSES UNDERLYING INTELLIGENT PERFORMANCE 14

2. SELECTED ASSESSMENT INSTRUMENTS FOR EVALUATING STUDENT LEARNING STYLES 16

3. COMPARISON OF BEHAVIORAL AND COGNITIVE OBJECTIVES 35

4. COMPONENTS OF INTEGRATED LEARNING STRATEGIES AND PROBLEM-SOLVING CURRICULUM 45

Figure

1. Contemporary version of the structure of the human information processing system 4

2. A network representation of information processing systems 6

3. An information processing sequential stage model of human memory 7

4. Schemata of control system components 9

5. Individual differences and cognitive processes 17

6. Samples of buggy subtraction algorithms invented by children 20

7. A network representation of content from a food service program: White sauces and variations 23

8. Process models for simple subtraction 25

9. Cognitive components suggested for vocational education curriculum 29

FOREWORD

Toward Excellence in Secondary Vocational Education: Using Cognitive Psychology in Curriculum Planning is a comprehensive review of recent advances in cognitive psychology that have relevance for vocational education. Recent research on learning and cognition have yielded important findings related to instructional processes. This publication describes cognitive knowledge for curriculum designers to help them develop problem-solving skills in the learner.

This publication is one of seven in a series produced by the Information Systems Division of the National Center. This series of information analysis papers should be of interest to all vocational and adult educators, including Federal and State agency personnel, teacher educators, researchers, administrators, teachers, and support staff.

The profession is indebted to Dr. Janet F. Laster for her scholarship in developing this interpretive manuscript. Dr. Laster is Assistant Professor, Department of Home Economics Education, The Ohio State University. She teaches graduate courses in learning theory and teaching strategies and is co-editor of a forthcoming teacher education yearbook of the American Home Economics Association, tentatively entitled *Vocational Home Economics Curriculum*.

Dr. Merlin Wittrock, Professor of Educational Psychology at the University of California at Los Angeles, and Dr. Richard J. Miguel, Research Specialist, and Dr. Judith Samuelson, Research Specialist of the National Center for Research in Vocational Education contributed to the development of this publication through their reviews of the manuscript. Staff on the project included Dr. William Hull, Senior Research Specialist; Dr. Oscar Potter, Graduate Research Associate; James Belcher, Program Associate; and John Tennant, Graduate Research Associate. Janet Ray served as word processor operator for this manuscript. Editorial assistance was provided by Janet Kiplinger and Judy Balogh of the Editorial Services at the National Center staff.

Robert E. Taylor
Executive Director
The National Center for Research
in Vocational Education

PREFACE

I am a vocational educator. Like other educators, I try to stay in touch with emerging theories and findings from supporting disciplines. This publication was developed in the quest to help me and other vocational educators "get in touch" with new developments from the field of psychology and apply those advances to the practice and improvement of vocational education.

My task was similar to that faced by vocational students or employees learning a new job, particularly a job using new technology. I had to learn—

- **new terminology**;
- **new concepts**, sometimes with conflicting meanings depending upon my point of view or experiences; and
- **new procedures** that were, more often than not, only implied.

Like an experienced employee trying to explain new technology to a new employee and expecting him or her to understand everything readily, I often felt like Alice in Wonderland when Caterpillar asked her to explain her meaning: "I'm afraid I can't put it more clearly . . . for I can't understand it to begin with!"

Readers may encounter similar frustrations when confronted with the original sources in the psychological literature. They may be frustrated by the new vocabulary with unclear meanings and confused by new concepts and methods. But they should persevere. Progress will be made as they gain additional insights from their work as vocational educators.

Psychology is experiencing what has been variously called a "cognitive revolution" (Resnick 1981, 1983; Wittrock 1978) and "boundary expansion" (Hilgard 1980; Tyler 1981). The newest psychological developments are coming from basic research using a variety of cognitive psychology research paradigms focused on the workings of the mind, or cognition. The research paradigm has influenced research in all branches of psychology, including experimental, personality, social, and instructional psychology, and in other fields such as linguistics, anthropology, artificial intelligence (the study of intelligence systems, such as computers), and education. Cognitive science, a new discipline that emerged in 1981, reflects the merger of interests among those pursuing the study of cognition from different viewpoints. This new emphasis on cognitive aspects of human behavior has resulted in an enormous body of research findings and the appearance of new publications. As Lachman, Lachman, and Butterfield (1979) note, "The [cognitive psychology] field . . . seems to have exploded in the 1960s and has not touched ground since" (p. xi).

As I reviewed the enormous body of cognitive psychology literature that has accumulated during the last 10 years, I searched for ways cognitive theory could help vocational educators prepare students for the changing workplace. My goal was to select references that seemed to reflect (1) the newest understandings of learners and their cognition as they learn and solve problems and (2) how their learning and cognition could be enhanced. Close attention was given to refer-

ences concerned with the cognitive processes and structures for learning to learn and problem solving. Since "it is now difficult to draw a clear line between instructional psychology and the main body of basic research on complex cognitive processes" (Resnick 1981, p. 60), sources were reviewed that reported psychological theory and research findings from experimental psychology and cognitive science as well as instructional psychology.

While reading the basic research reports, I was well aware that psychology is a descriptive, not a prescriptive, science and that basic research is not conducted with applications in mind. Because of this, "The gap between cognitive psychology and education has been and continues to be substantial" (Wagner and Sternberg 1984, p. 199). Cognitive psychology cannot give specific direction to us as vocational educators since it is not a prescriptive science, and caution must be shown as we attempt to apply the concepts and research methods to the practice of vocational education. However, this gap is being bridged somewhat by fundamental cognitive research in instructional psychology. "Instructional psychology is no longer basic psychology *applied* to education. It is [now] concerned with . . . mental processes and how their development can be enhanced through instruction" (Resnick 1981, p. 60). Regardless of this problem, cognitive psychology is an important source for guiding curriculum decisions. As Fioden (1981) notes, "Social science (such as psychology) probably makes a greater contribution through the concepts it introduces and the methods it develops than through the conclusions it draws" (p. 105). The concepts coming from cognitive theory and research and the methods being used offer benefits to vocational educators, particularly curriculum planners accomplishing the goals and objectives of vocational education in a changing social and economic environment.

To examine the concepts and methods from cognitive psychology and their potential implications for helping vocational educators accomplish curriculum development tasks, this publication is divided into three parts. The first chapter reviews the needs and characteristics of vocational education students and the objectives of vocational education to which cognitive psychology is applicable. The second chapter examines the recent advances in cognitive psychology—the new concepts and research methods being introduced—that may be helpful to vocational educators. The third chapter suggests implications for what and how we should teach in vocational education. This chapter concludes with specific suggestions curriculum planners can use. The final chapter summarizes the advances and implications for curriculum and instruction and draws some final conclusions for helping students develop problem-solving and learning skills. Finally, recommendations for applying cognitive psychology concepts to vocational education are proposed.

EXECUTIVE SUMMARY

The dynamic nature of the workplace has placed increased emphasis on a prospective employee's ability to learn. Changing jobs sometimes as many as 10 times in a lifetime, today's worker must often acquire new skills and know how to adapt existing skills to different environments. Reasoning and problem-solving abilities are at a premium. Curriculum developers should be aware of recent advances in cognitive psychology to prepare vocational education students adequately for occupational mobility and advancement on the job.

This publication was written for curriculum developers and vocational education instructors. It provides an understanding of cognitive concepts and methods using an information processing paradigm and shows how to apply this knowledge in the development of curriculum and instructional plans. This publication will help vocational educators provide learning environments enabling students to develop thinking and learning skills needed for problem solving and learning throughout their careers. Cognitive components affecting behavior and problem solving are reviewed, implications from these new developments suggest the need for an integrated knowledge structure of core concepts and procedural knowledge as well as thinking and learning skills, and instructional strategies are recommended. This review of advances in cognitive psychology reveals the following:

- The human cognitive system intervenes between the teaching-learning environment and the learner's problem-solving behavior.
- Intelligent problem solving requires extensive accessible conceptual and procedural knowledge and thinking skills.
- Learning is an active, constructive process rather than a memorizing process.
- Learners control their learning and behavior with the knowledge structures, thinking skills, and learning skills they possess.
- Self-monitoring skills are important for learning and solving all types of problems.
- Cognitive knowledge structures and processes can be specified and represented with semantic network diagrams, production systems, flowcharts, and programs.

Advances in cognitive psychology have the following implications for curriculum and instruction in vocational education:

- The content of vocational education needs to be expanded to include problem-solving, self-monitoring, and learning skills.
- An integrated knowledge structure should be taught involving generic core concepts and procedures, and condition patterns of general problem-solving, self-monitoring, and learning skills.

- Critical problem-solving, self-monitoring, and learning skills should be developed so vocational students can use them automatically to solve problems.

Clearly, some advances from cognitive science have potential for helping vocational students develop problem-solving and learning skills needed for successful careers in the workplace. Vocational education programs provide an ideal learning environment for developing general problem-solving, self-monitoring, and learning skills; however, vocational educators must do the following if students are to gain from the opportunity:

- Have and use curriculum materials that require students to process information for concept formation.
- Have and use curriculum materials and experiences that help students develop procedures for problem-solving, self-monitoring, and learning strategies.
- Provide firsthand experience with employment problems and tasks.
- Teach underlying cognitive abilities that help students achieve success with vocational tasks or problems.

Although progress is being made toward identifying the cognitive components of reading, mathematics, and science tasks, almost nothing is known about the specific cognitive processes involved in solving vocational tasks. Likewise, metacognitive skills such as planning, decision making, problem representation, and self-monitoring need attention from learning researchers. The following recommendations are made:

- A problem-solving and learning curriculum component should be developed for integration into high school and adult programs.
- Local vocational programs should institute an information processing approach to learning, using a problem-solving approach with occupation-specific tasks and problems incorporated as a means, not an end, for learning.
- Curriculum materials and experiences that require students to process information and form concepts—including concepts of condition patterns—as well as procedure rules need to be developed for vocational programs.
- Practice opportunities for solving both routine and new problems need to be incorporated throughout the vocational program.
- A combination of instructional strategies to help students learn by rules, discovery, and reflecting on their own thinking processes should be used throughout the vocational education curriculum.
- Teacher education programs should help vocational education instructors develop the cognitive concepts and methods needed to help students acquire learning and problem-solving skills.
- Model career development systems that have literacy and general education components should be created for students with special needs.

INTRODUCTION

Changing Workplace

Vocational education is faced with the problem of preparing students for the uncertain demands of a new and complex era. New technology, global economic competition and interdependency, and demographic and social changes are constantly transforming the workplace (National Academy of Sciences 1984). Some jobs are eliminated while others are created. For example, some 20 million jobs were created between 1969 and 1980, and an additional 25 million new jobs are expected between 1982 and 1995 (Personick 1983).

As jobs change, the skills required of workers may change, too (National Academy of Sciences 1984). From their first job to retirement, individuals may have as many as 10 employers and at least as many jobs (Hall 1982). Such change requires that a successful employee be able to learn and adapt to the demands of the changing workplace. Vocational education must prepare its graduates in these skills.

Needs of Vocational Education Students

The ability to learn was identified as "the essential hallmark of the successful employee" by the Panel on Secondary School Education (National Academy of Sciences 1984, p. x). This panel studied the needs of high school graduates from the perspective of private business and public institution employers and identified the components of basic high school education needed for successful, upwardly mobile 45- to 50-year careers. It concluded that every high school graduate needs virtually the same competencies as those going on to college:

- The ability to learn and adapt to changes in the workplace
- Core general education competencies
  - —a command of the English language
  - —reasoning and problem-solving skills
  - —reading, writing, and computing skills
  - —science and technology
  - —oral communication
  - —constructive, effective interpersonal skills
- A positive attitude and sound work habits

Like other recent studies of American education (Adler 1982; Education Commission of the States 1983, 1984; Gisi and Forbes 1982; Sizer 1984), this panel concerned itself with developing an educated person. Central to its description of an educated person was the ability to reason and solve problems.

Will high school graduates be properly prepared? Results from recent studies create concern:

- Cognitive skills and abilities are more important for job success than other job performance attributes (Klemp 1977; National Academy of Sciences 1984).

- The mean reading and math scores of high school seniors enrolled in concentrated vocational education programs are significantly lower than those of college-bound seniors.

- More than 400,000 vocational education students have identifiable handicaps, including learning disabilities (Bottoms and Copa 1983, p. 349).

- Although the majority of 17-year-olds achieve minimum skills, only a minority achieve the higher level skills needed for future jobs. These higher level skills include—

  —evaluation and synthesis skills,
  —critical thinking,
  —problem-solving strategies (including mathematical problem solving),
  —organization and reference skills,
  —application,
  —creativity,
  —decision making drawn from incomplete information, and
  —communication skills used in a variety of modes.

- The proportion of 17-year-olds achieving higher level skills has declined over the past 10 years.

- If these trends continue, as many as 2 million students may graduate in 1990 without the necessary employment skills—reasoning and problem-solving skills. (Gisi and Forbes 1982)

Curriculum Development and Cognitive Psychology

The reality of our changing society requires a critical examination of the curriculum and instruction of vocational education. How to prepare students for success in the workplace throughout their careers is now a concern for vocational educators. What and how to teach become important questions.

One source of guidance for vocational educators involved in curriculum and instructional decision making is cognitive psychology.

Because cognitive psychology is concerned with the nature of intelligence and how people think (J. R. Anderson 1980), it can expand our understanding about—

- what goes on in students' heads while learning and performing tasks,

- how students solve problems and what the "higher mental processes" are,

- what students need to learn to perform and to solve problems intelligently, and

- how students learn and how they acquire knowledge and skills.

Because cognitive psychology is a descriptive, not a prescriptive, science, research findings cannot generate new curricula for vocational educators. However, implications can be drawn from cognitive psychology research and theory that suggest ways educators can help students to—

- develop cognitive skills needed for successful performance in the workplace and

- learn how to learn and continue learning throughout their careers.

This publication is intended to—

- help vocational educators gain an understanding of the cognitive concepts and methods evolving from recent cognitive research and

- suggest ways vocational educators might apply these concepts and methods as they prepare their students for the workplace.

ADVANCES IN COGNITIVE PSYCHOLOGY: A BASIS FOR CURRICULUM AND INSTRUCTION DECISIONS

Major advances in cognitive psychology have implications pertinent to improving vocational education. New cognitive concepts and methods being introduced expand and help integrate current understandings of human behavior and suggest new dimensions for vocational education curriculum and instruction.

As researchers have pursued various cognitive theories, especially information processing theories, and have compared their findings with neurological and educational research findings, a new view of learners, learning, and intelligence has emerged. This new view contradicts the implied behaviorist view that the learner is a passive consumer of information; that learning is controlled by immediate, sensory input from the environment; and that intelligence is a static, unchanging phenomenon.

Beginning with a broad information processing sequential stage model and proceeding to smaller alternative theories (see Lachman, Lachman, and Butterfield 1979), researchers are beginning to answer questions about our incredibly complex cognitive system and how we as educators might intervene to effect intelligent, competent performance. Although findings are rarely conclusive and confusion exists on the frontier of any new science, helpful concepts are emerging. Expanded understandings are being gained about (1) the structure and capabilities of the human cognitive system, (2) the cognitive components of competent and intelligent problem-solving performance, (3) intelligence as modifiable cognitive strategies and processes, (4) learning as a constructive thinking process, and (5) learners as controllers of learning and behavior.

Newly established cognitive task analysis methods have helped to identify cognitive processes and knowledge structures needed for solving complex everyday problems and performing real-world tasks competently and intelligently. These new task analysis methods give educators additional tools for describing changing conceptual states. By employing combinations of these methods, cognitive components of two vocational tasks—the bookkeeping problem (see Bhaskar, Herstein, and Hayes 1983; Dillard, Bhaskar, and Stevens 1982; Stevens, Bhaskar, and Dillard 1981) and the electronic circuit failure problem (see Rasmussen and Jensen 1974)—have been identified.

Cognition: An Intervening Information Processing/Controlling System

One current view of the cognitive system is that it is essentially a *human information processing system*. The critical elements of this information system, as depicted in figure 1, appear to include four major process-oriented components: sensory input and perception, memory representations, control processes, and output and response mechanisms (Calfee 1981; Norman 1981; Wittrock 1980). These components shape the problem-solving efforts and intelligent actions of students (Glass, Holyoak, and Santa 1979; Mayer 1983; Simon 1980). Neurophysiological findings of brain functioning are consistent with some findings in cognitive psychological analysis of perception, memory, and learning (Calfee 1981; Wittrock 1978, 1980).

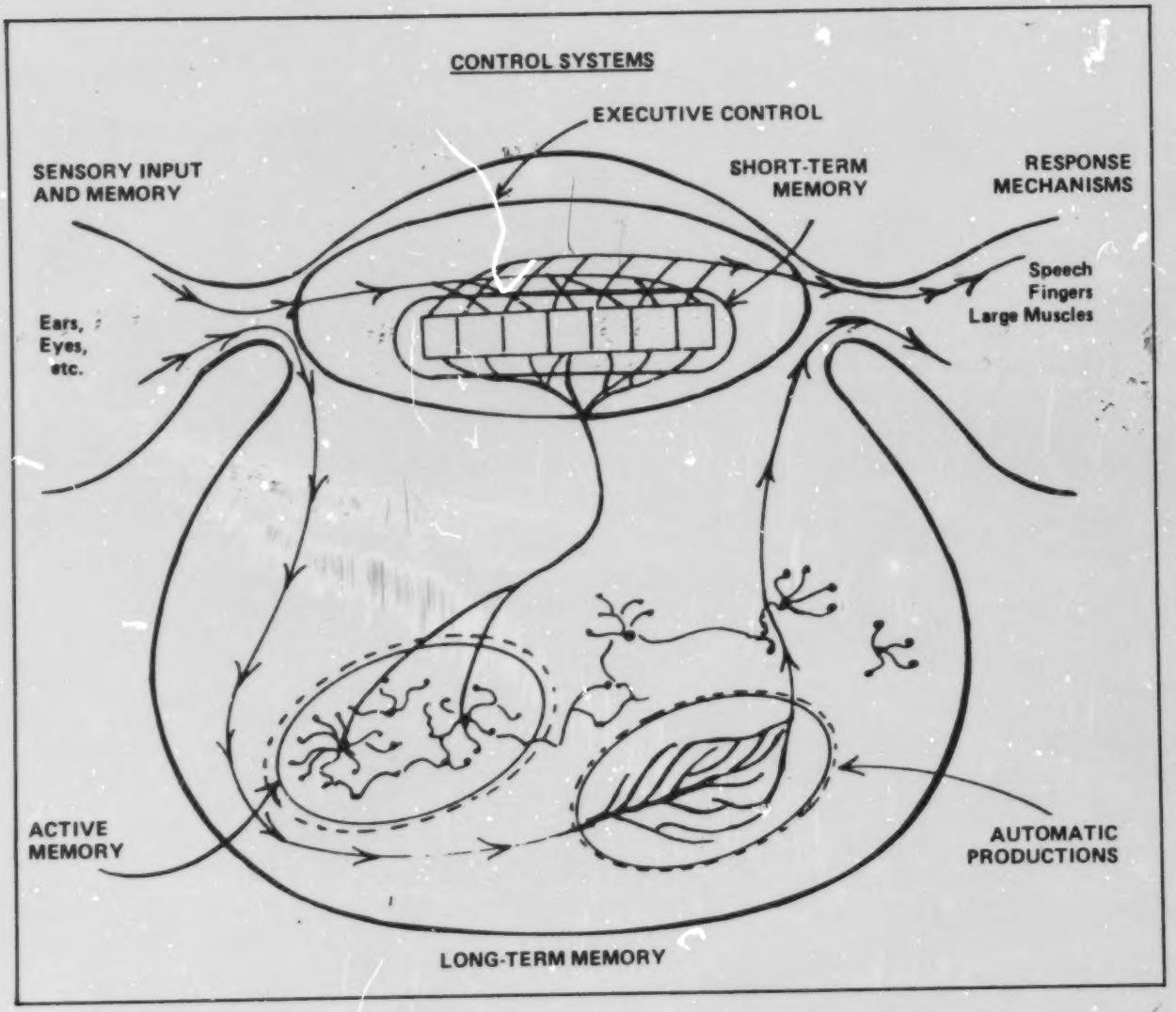

Figure 1. Contemporary version of the structure of the human information processing system

SOURCE: Used with permission of the American Educational Research Association, from Calfee (1981, p. 9)

Perception: A Constructive Process

Information from the environment is received simultaneously or successively through a variety of channels: visual, auditory, tactile, olfactory, kinesthetic, interceptive, and so forth (Das 1984b). Perception can be based entirely on sensory input, that is, bottom-up perception, or higher level information from memory, as in top-down perception. Both perception processes are used in varying degrees depending on the type of input. For example, top-down perception is most important in perceiving speech input as people tend to "fill-in" parts of speech automatically from memory on the basis of context.

Perception is, thus, a process of construction, correcting and creating reality as information is used from the environment and from memory to correct errors in speech or to recognize patterns when perceiving visually printed words, pictures, faces, and so forth. Consequently, perception and memory are closely integrated (Glass, Holyoak, and Santa 1979).

Memory: A Representative, Associative Network

Human memory, from an information processing perspective, is depicted as a continuously active system consisting of short-term or primary memory (STM) and long-term or secondary memory (LTM). Long-term memory contains permanent knowledge and skills. Until recently, memory was viewed as a serial multistorage system, receiving, modifying, storing, retrieving, and otherwise processing information one "chunk" at a time, first in short-term memory and later in long-term memory (Klatzky 1980; Lachman, Lachman, and Butterfield 1979).

At present, memory is viewed as a highly organized, vast, associative network of interacting chunks of information. This network of schemata is the result of comprehending and understanding these chunks of information. Two kinds of information are stored: conceptual, that is, propositional or declarative knowledge, and procedural or algorithmic knowledge.

"A 'chunk' is any perceptual configuration (visual, auditory, or what not) that is familiar and recognizable" (Simon 1980, p. 83). A chunk may be a chessmen or chessboard configuration, a syllable or word, hackneyed phrase, number or formula, or a procedure. These chunks of information may be stored in representative codes (Glass, Holyoak, and Santa 1979), or schemata (Calfee 1981), either as analogic (imagery or picture) codes or analytic (language or words) codes. Analogic, episodic codes resemble what they represent, such as personal experiences, whereas analytic, semantic codes represent abstract meanings, such as concepts, rules, or procedures (Glass, Holyoak, and Santa 1979). These representative codes or schemata can be depicted by diagrams like the one in figure 2.

Diagrams like this semantic network can represent concepts and procedures. Procedures can be further and more completely represented by flowcharts, programs, or production systems like those in figures 3 and 8.

In general, verbal inputs seem to be more easily integrated into an organizational structure, and consequently, cues to recall verbal input are more easily generated than cues for visuals (Glass, Holyoak, and Santa 1979). From a variety of studies, Simon (1981) hypothesizes that "memory is an organization of list structures (lists whose components can also be lists), which include descriptive components (two-termed relations) and short (three-element or four-element) component lists" (p. 89).

Human long-term memory can hold an unlimited number of chunks, but short-term memory is thought to be decidedly limited. Initially, seven chunks seemed to be the outside limit for short-term memory, but now the limit appears to be two chunks. The discrepancy may lie in the recoding of stimuli into a smaller number of more complex chunks (Simon 1981). Rather than storing three small chunks—"c," "a," and "t"—storing a combination of the three chunks into "cat" would reduce the number of chunks held in memory from three to one chunk, thereby increasing the amount of information that can be stored in short-term or working memory at one time.

Until recently, memory in either STM or LTM was thought to depend on the capacity limits of STM, the type of information code—such as acoustical, semantic, or visual—or the forgetting characteristics of STM. Memory retention is now thought to be influenced by how much the information is processed when it is perceived (Craik and Lockhart 1972; Houston 1981).

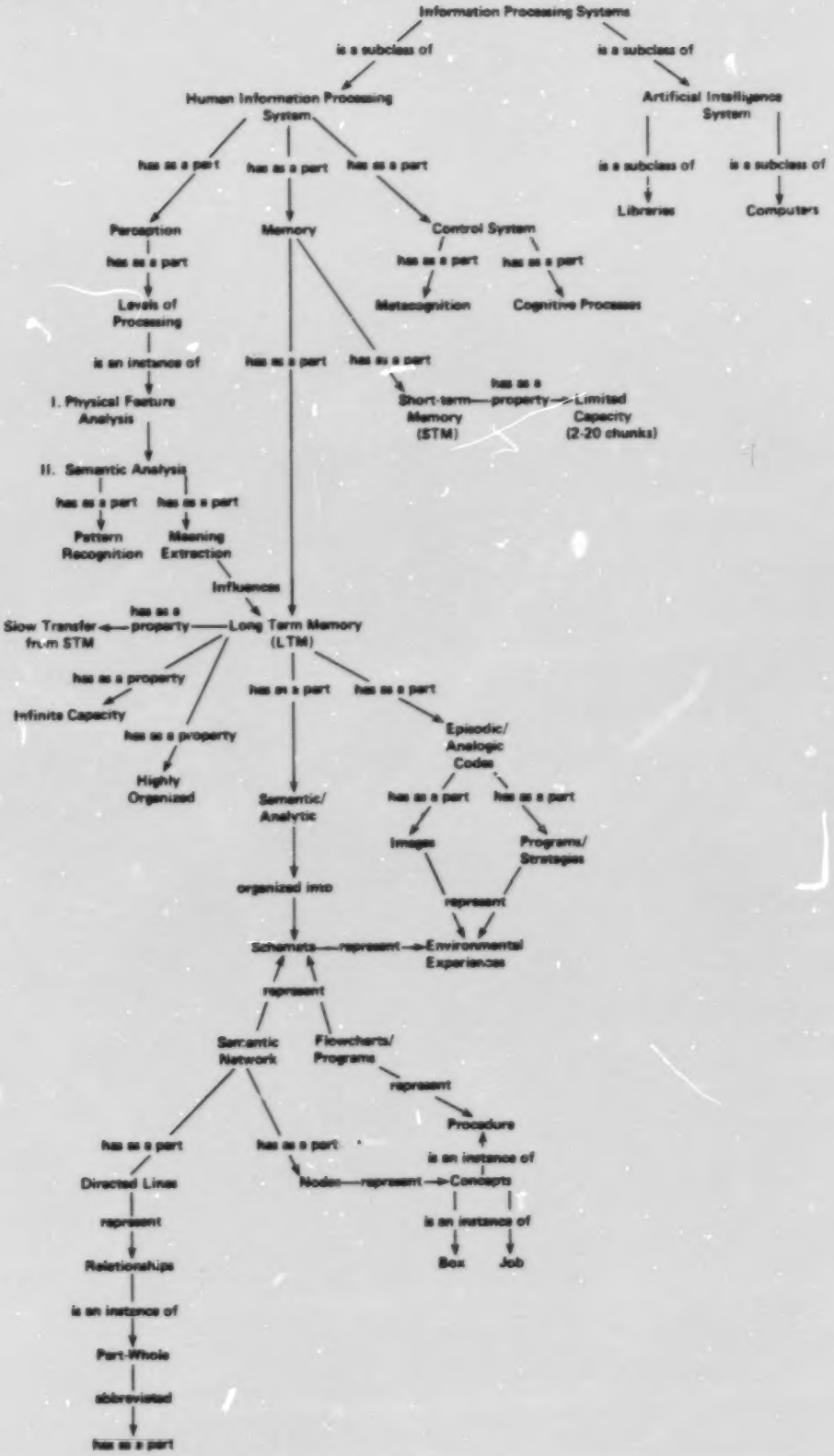

Figure 2. A network representation of information processing systems. This represents the major elements of the human information processing model and some details.

SOURCE: Adapted from Posner (1978).

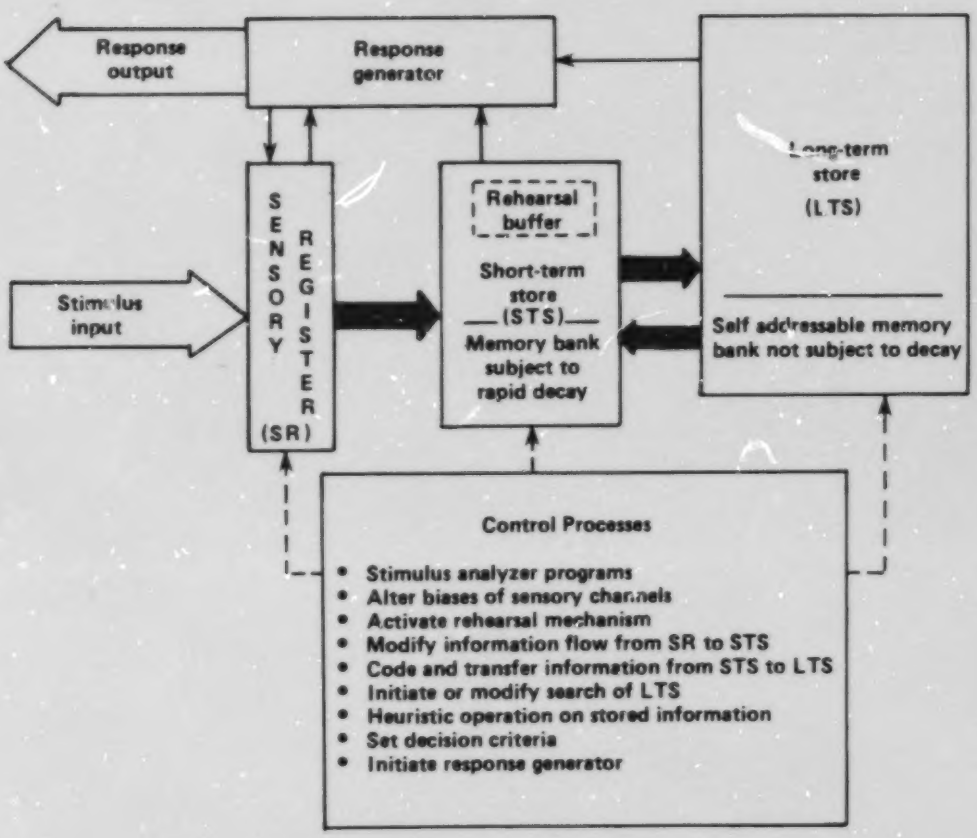
Response output
Response generator
Long-term store (LTS)
Rehearsal buffer
SENSORY REGISTER (SR)
Short-term store (STS)
Memory bank subject to rapid decay
Stimulus input
Self addressable memory bank not subject to decay
Control Processes
• Stimulus analyzer programs
• Alter biases of sensory channels
• Activate rehearsal mechanism
• Modify information flow from SR to STS
• Code and transfer information from STS to LTS
• Initiate or modify search of LTS
• Heuristic operation on stored information
• Set decision criteria
• Initiate response generator

Figure 3. An information processing sequential stage model of human memory

SOURCE: R. M. Shiffrin and R. C. Atkinson (1969). Copyright 1969, American Psychological Association. Reprinted with permission.

Memory does not seem to be improved by repeating or rehearsing information (Craik and Lockhart 1972). However, retention generally increases as the depth of processing increases, from shallow processing where the individual is concerned with analyzing physical or sensory features of the information to deep processing where the individual is concerned with semantic analysis—recognizing patterns and meanings—and, finally, elaborative processing. Craik and Tulving (1975) illustrated this phenomenon by asking individuals to make judgments about words perceived over very, very short lengths of time. In the shallow-processing situation, the individuals had to decide if words were typed in capitals. In the deep-processing condition, they had to decide if the words rhymed with a designated word. Finally, in the deepest, elaborative processing level, the individuals judged whether the stimulus word fit into a sentence frame. A surprise test showed that recall increased as depth of processing increased. These findings suggest the importance of meaning in retaining information in long-term memory. Other studies have identified the same relationship between levels of processing and retention, but some also indicate that more effort and attention are required for deep-processed information than for shallow-processed information (Houston 1981).

Of interest to vocational educators is the finding that the depth of processing during study is related to the quality of learning outcomes (Schmeck and Grove 1979; Watkins 1983). Students who used shallow, reinteractive study practice (memorizing and generally repeating the information in its original form) had low grade point averages, low ACT scores, or diminished quality of learning outcomes on regular class learning tasks; students with high grade point averages, ACT scores, and quality learning outcomes used deep, elaborative study approaches. They tried to "see the connection between different parts" and to "think about the structure as a whole" (Watkins 1983). Schmeck and Grove (1979) found deep, elaborative processors spent study time in several ways: classifying, comparing, contrasting, analyzing, and synthesizing information from different sources. These students had high scores on the Inventory of Learning Processes' (ILP) Synthesis-Analysis Scale, which has been shown to be related positively to critical thinking ability, achievement motivation, efficiency in note taking, and verbal learning, but negatively related to anxiety (Schmeck, Ribich, and Ramanaiah 1977). In addition, successful students (so judged by their high grade point average and ACT scores) were also found to process information in elaborate ways: they visually imagined personal illustrations or paraphrased and tried to fit the new information into a personal organizational framework. Although they were concerned with the whole, successful students were also cognizant of details in relation to the whole.

Comprehension rather than memorization seemed to be the goal of successful students. They seemed to be concerned with creating and adding to their schema of concepts (although they may not have been conscious of this). From their performance, these students seemed to produce knowledge that can be easily applied and remembered.

The approach of successful students was quite different from the memorizing approach of unsuccessful students. The unsuccessful performance of the students who tended to reproduce the knowledge would support the assumption of Doyle (1983), who noted that memorizing can produce knowledge in a form that is not easily applied to new situations.

Cognitive Strategies and Processes: A Control System

Like artificial intelligence systems, the human intelligence system is thought to have a central control system with subsystems that together determine what and how information will be processed (Calfee 1981; Kirby 1984; Wagner and Sternberg 1984). Most important in this central processing system is thought to be *metacognition*:* this consists of cognitive strategies and metacognitive knowledge (Kirby 1984, see figure 4). Metacognition subsumes general transferable problem-solving skills, including metamemory and metalearning (Brown 1978). In addition, evidence suggests this central control system directs the motor control system that is so much a part of skilled vocational performance (Posner and Keele 1973).

Information processing can be *automatic* or *controlled* (Schneider and Shiffrin 1977; Shiffrin and Schneider 1977). Automatic processing occurs without conscious attention, enabling tasks to be carried out simultaneously, for example, as tasks are carried out by skilled readers or day-care workers. In contrast, controlled processing occurs with the conscious attention of the individual, and consequently, only one procedure can operate at a time. Automatic processing requires a great deal of training and practice and a fast-action, pattern-recognition system. Furthermore, retrieval is thought to be easier and quicker if the information is hierarchically

*The prefix *meta*, as used in the cognitive psychology literature reviewed, seems to be referring to higher, more generalizable cognition. At times, *metacognitive* refers to knowledge, and at other times, it refers to process.

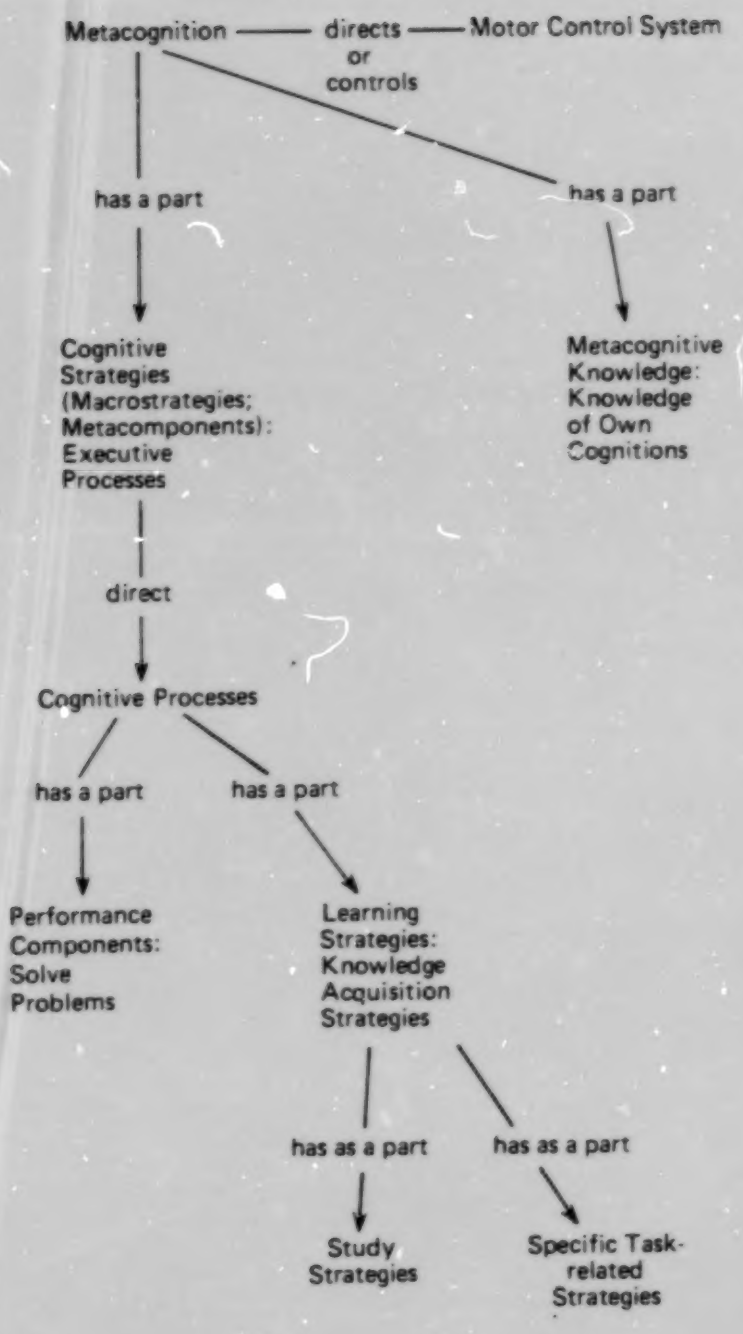

Figure 4. Schemata of control system components

organized with functional properties at the highest levels and structural properties at the lower levels (Chase and Chi 1981).

Considering this notion, the problem-solving capacity of individuals, such as vocational students, can conceivably be increased if routine processing aspects of the problem-solving task are automatic (Frederiksen 1984). For example, with practice, the basic skills and knowledge required in typing or bookkeeping can be used automatically, making possible the simultaneous information processing required of a skilled typist or bookkeeper.

Cognitive strategies (Kirby 1984) or macrostrategies (Biggs 1984)—those controlling metacomponents, or executive planning and decision-making processes (Sternberg 1984)—interpret and plan what to do with stimulus information and feedback, monitor what we are doing, evaluate what we have done (ibid.), and modify other processes (Lawson 1984). Examples of these executive strategies include deciding upon the processes needed to solve the problem, sequencing cognitive processes into a worthwhile strategy or plan, and monitoring and evaluating one's solution processing (see table 2).

Metacognition also refers to "knowledge about one's own cognitions rather than the cognitions themselves" (Brown 1978, p. 79). Lawson (1984) calls this "metacognitive knowledge." "Self-interrogation [or self-monitoring] concerning the state of one's own knowledge during problem solving is an essential skill in a wide variety of situations, those of the laboratory, the school, or everyday life" (Brown 1978, p. 80). Conscious executive control of cognition depends on metacognitive knowledge and is the "essence of intelligent activity" (ibid., p. 79).

These higher level processes are complemented and supported by *cognitive processes* (Kirby 1984). Two types of such cognitive processes are included in the literature: performance components (Sternberg 1984) and learning (see Biggs 1984; McCombs 1981-1982, 1984; O'Neil 1978; O'Neil and Spielberger 1979) or knowledge acquisition strategies (Sternberg 1984).

Performance components are used in actually solving the problem task. Such cognitive processes include encoding, inferring, applying, and comparing (Sternberg 1984). *Learning strategies* are used to learn specific new materials or procedures, for example, how to solve an arithmetic or automotive problem. These learning strategies range from general strategies—including learning styles and study strategies—to more specific domain or task-related microstrategies. The higher level, metacognitive strategies seem to be more transferable than study strategies or domain- or task-specific microstrategies in that order (Biggs 1984; Wagner and Sternberg 1984).

From the juxtaposition of this research with that of neuroscience and education, Wittrock (1981a) draws several conclusions:

- Our brains have characteristic processes for encoding and storing information.
- The arousal and attentional processes in the limbic system and brain stem and the planning and organization processes in the frontal lobes interact with each other and influence behavior and learning.
- Individuals differ in their uses of the attentional and organizational cognitive processes of the brain.
- Learning disabilities are sometimes caused by lesions of the brain, whose location and effects are increasingly becoming known. (pp. 12-13)

(For reviews of this literature see Chall and Mirsky 1978; Wittrock 1979b, 1980, 1981b.)

Output and Response Mechanisms

Skilled action is the goal of vocational education and the intended outcome of cognition. Expert, rapid, and accurate performance in manual activities or language and thought is recognized as skilled action (Posner and Keele 1973). The output and response mechanisms—speech, muscles, and limbs--produce the sound and movement necessary for skilled action. Although these components are necessary for skilled action, smooth, automatic interaction of the central control system with all other human processing components is essential.

These components compose the conventional view of a pure, cognitive system. Advances have been made in understanding its structure and functions, and the components seem reasonable. Yet some cognitive scientists (Geschwind, Johnson-Laird and Lakoff, Norman, Simon, and Winograd in Norman 1981) are beginning to develop new theories and models that reflect a consideration of other aspects of human behavior, of interaction with other people and the environment, of cultural influences, and so on.

For example, Norman (1981) questions whether or not the pure, cognitive system—which focuses on pure reason—is indeed the pinnacle of human functioning. He proposes that cognitive scientists reconsider the functioning of human cognitive processing and examine the relationships between the cognitive system, the emotional system, and the regulatory system. He asserts that "emotions play a critical role in behavior" (p. 275). Similarly, McCombs (1984) "assumes that both a cognitive and affective system are involved in generating perceptions of task requirements" (p. 23-24) as she proposes a motivational skills model for military trainees. Until now, this aspect of human behavior has been all but ignored by behaviorist and cognitive psychologists. This concern for the role of affect is an advancement in cognitive theory worth watching for additional insights.

Cognitive Components of Competent, Intelligent Problem-solving Performance

Some progress is being made in identifying the cognitive components of competent, intelligent performance (Simon 1980; Wagner and Sternberg 1984). Comparisons of novices and experts as they solve problems (Larkin 1980; Simon 1980) and examination of the cognitive components involved in intellectual ability (IQ) tests (Feuerstein et al. 1980; Pellegrino 1979; Sternberg 1984; Wagner and Sternberg 1984) show two critical components:

- Extensive, accessible knowledge
- Cognitive skills

Extensive, Accessible Knowledge

One major point of cognitive research is that "there is no such thing as expertise without knowledge—extensive, accessible knowledge" (Simon 1980, p. 82). This conclusion resulted from comparisons of expert and novice problem solvers. A study of novice and expert chess players found that experts do not have larger or better memory capacities than novice players. Instead, expert players have approximately 50,000 chunks of specific knowledge about chess. These chunks are in the form of highly organized chessboard configurations (Newell and Simon 1972).

Reflecting on the large number of chunks of specific knowledge, Norman (1980) estimated from his experience that expert cooks also need approximately 50,000 "kitchen facts" about food preparation and cooking. Judging from the time required for a beginner to become a grand master chess player and for great composers to create their first great production, a 10-year period is estimated for gaining the necessary knowledge for expertise (Mayer 1983). Greeno

(1980) concluded from his review of knowledge theory and problem solving that there is no scientific basis for reducing intensive, disciplined training for individuals who wish to be creative in their field of endeavor. In other words, people who are good at marketing, preparing gourmet meals, designing landscapes, managing an office, or resolving scientific issues are probably good in part because they have extensive, domain-specific knowledge (Mayer 1983).

Two types of knowledge—conceptual and procedural—are needed for solving problems well (Glaser 1984; Larkin 1980). *Conceptual knowledge* is composed of facts, principles, and abstractions or concepts, whereas *procedural knowledge* represents "knowledge about the application of what they [individuals] know" (Glaser 1984, p. 99).

Procedural knowledge seems to be composed of actions to be taken and the conditions under which these actions should be taken. Computer-implemented models of intelligence write these procedures in terms of "productions" or units. The productions consist of an action and a condition specifying when the action is to be taken. Artificial intelligence models of the mind assume that the human mind has an immense number of these condition-action units (Larkin 1980).

Expert problem solvers have a tightly connected schema composed of these aspects of knowledge. However, the procedures seem to be subsumed by principles and abstractions (Glaser 1984).

Aside from the issue of extensive knowledge, novice and expert problem solvers differ in the way they organize knowledge in memory. In a novice-expert study, experienced physicists were found to have their knowledge organized in large chunks—principles as part of large-scale coherent units—whereas novices had their knowledge in small units. The large chunks in the experts' memories seemed to be organized in clusters rather than individually like the knowledge of the novices (Larkin 1980).

These findings agree with other studies that indicate knowledge is more retrievable when it is grouped, chunked, or clustered by conceptual categories or organized with familiar retrieval cues.

In addition, hierarchical, thematic organization arrangements enhance accessibility (Bower and Clark 1969; Glass, Holyoak, and Santa 1979). For example, Glass, Holyoak, and Santa (1979) found that individuals given words to learn that were organized in a hierarchical classification scheme recalled more words later than did individuals given the same words in random order. Similarly, physics students given instructional materials that stressed a hierarchical organization performed better on a variety of tasks than did students given materials stressing a linear sequential organization (Larkin 1980). Furthermore, recall seems to be enhanced if knowledge is organized in categories that contain not more than five chunks or units, such as words. Although the issue of coding is complicated, it appears that, in general, verbal inputs may be most easily integrated into an organizational structure, and consequently, cues are more easily generated to recall verbal input than cues for pictures or other visuals (Glass, Holyoak, and Santa 1979).

Cognitive Skills

"Knowledge is necessary, but not sufficient, for performance. [Individuals] vary not only in what they know but in what they do with what they know" (Brown and Campione 1982, p. 221). In addition to differences between novices and experts in the amount and way knowledge is organized, different cognitive strategies and processes are used.

Most important of these seem to be *general metacognitive strategies, or executive processes*, that combine with knowledge to solve a variety of problems (Simon 1980; Wagner and Sternberg 1984). The general processes at the metacognitive level appear to be the most transferable, and

consequently, attention is being given currently to these skills rather than to lower order performance components (see figure 4). Three general metacognitive executive skills that appear to be the most transferable and that are receiving much attention are: planning, representation (Greeno 1980), and self-monitoring, self-management skills (Belmont, Butterfield, and Ferretti 1982; Brown, Campione, and Day 1981; Rigney 1980). Considering the fact that there are many different types of problems requiring different problem-solving skills, these three skills become important in deciding what is best to do in solving different problems satisfactorily (Greeno 1980).

Feuerstein et al. (1980) have identified some of the important *cognitive processes* underlying intelligent performance on intelligence tests. Feuerstein and his associates, through their research with "retarded" adolescents, identified the cognitive deficiencies preventing immigrant adolescents from functioning in a technological society. Deficient cognitive functions are defined as "a product of a lack of, or insufficiency of, mediated learning experience and are responsible for, and reflected in, retarded cognitive performance" (p. 71). These deficiencies seem to indicate cognitive functions (listed in table 1) that are prerequisite for intelligent performance in a complex society.

Sternberg (1984) has identified what he calls "principal abilities underlying intelligent behavior," which include metacognitive and performance components (see table 1). Of these, five appear to be planning skills:

- Recognizing and defining the nature of a problem
- Deciding upon the processes needed to solve the problem
- Sequencing the processes into an optimal strategy
- Deciding upon how to represent problem information
- Allocating mental and physical resources to the problem (p. 40)

The fourth ability, deciding upon how to represent problem information, parallels representation as a major skill. The important skills identified by Feuerstein appear to be metacomponents and performance components. These examples provide a beginning basis for evaluating student differences and needs and for identifying important cognitive objectives.

Another important general metacognitive component is self-monitoring (or self-management). This skill also appears to be necessary for successful problem solving (Bloom and Broder 1950; Brown, Campione, and Day 1981; Whimbey 1980). Although not all children and adults are conscious of their problem-solving and learning strategies (Whimbey and Whimbey 1975), and many may even be unable to explain them (Wagner and Sternberg 1984), students having these abilities are able to learn and solve problems accurately in order to achieve a desired goal (Bloom and Broder 1950; Brown, Campione, and Day 1981; Whimbey 1980). Rigney (1980) has identified a set of self-monitoring skills that represent the kinds of internal dialogue vocational students can use to maintain attention, evaluate learning strategies or performance, and tell themselves what they know and don't know when learning or solving problems. In the following list, the skill is given first, followed, in parentheses, by the questions students can ask themselves to develop these skills.

- Keeping one's place in a series of operations.
  (Where was I?)
- Knowing when a subgoal has been reached.
  (Am I done with this?)

TABLE 1

EXAMPLES OF COGNITIVE STRATEGIES AND PROCESSES UNDERLYING INTELLIGENT PERFORMANCE

Prerequisite Cognitive Functions (Feuerstein et al. 1980)	Principal Abilities Underlying Intelligent Behavior (Sternberg 1984, p. 40)
Input Phase	
1. Focusing perception*	1. Recognizing and defining the nature of a problem*
2. Using systematic exploratory behavior*	2. Deciding upon the processes needed to solve the problem*
3. Applying receptive verbal tools and concepts affecting discrimination	3. Sequencing the processes into an optimal strategy*
4. Gaining spatial orientation, including stable system of reference	4. Deciding upon how to represent problem information*
5. Gaining temporal orientation	5. Allocating mental and physical resources to the problem*
6. Conserving constancies in size, shape, and so forth across variations of object	6. Monitoring and evaluating one's solution processing*
7. Being precise and accurate in data gathering	7. Responding adequately to external feedback
8. Exercising a capacity for considering two sources of information at once as unit of organized facts, not piecemeal	8. Encoding stimulus elements effectively
Elaboration Phase	9. Inferring relations between stimulus elements
9. Experiencing and defining problem*	10. Mapping relations between relations
10. Selecting relevant cues in defining problem*	11. Applying old relations to new situations
11. Exercising spontaneous comparative behavior	12. Comparing stimulus elements
12. Combining and coordinating several units of information	13. Responding effectively to novel kinds of tasks and situations
13. Demonstrating a need for summative behavior*	14. Automatizing information processing effectively
14. Projecting virtual relationships	15. Adapting effectively to the environment in which one resides
15. Displaying an orientation toward need for logical evidence	16. Selecting environments as needed to achieve a better fit of one's abilities and interests
16. Internalizing one's behavior	17. Shaping environments to increase one's effective utilization of abilities and interests
17. Using inferential-hypothetical thinking	
18. Using hypothesis testing	
19. Displaying planning behavior*	
20. Elaborating on categories	
Output Phase	
21. Using empathetic communication	
22. Initiating new responses	
23. Completing a figure by transporting missing part	
24. Relating events or objects to past or future experience	

*Metacognitive, executive processes.

- Detecting errors and recovering from those errors either by making a correction or by retreating to the last operation known to be correct.
  (Is this right? Should I go back?)

- Learning the structure of a series of operations.
  (How are these related?)

- Identifying areas where errors are likely.
  (Where could I make a mistake?)

- Choosing a strategy that will reduce the possibility of error and will provide easy recovery.
  (What should I do? Which approach would be best?)

- Identifying the kinds of feedback that will be available at various points and evaluating the usefulness of them.
  (Where can I find out how I'm doing? Who can help me? Is this feedback valid and reliable?)

- Looking back to detect previous errors.
  (Have I done everything? Is it accurate?)

- Keeping a history of what has been done so far and what should come next.
  (What's been done? What do I do now?)

- Assessing the appropriateness of the outcome.
  (Is this what I should have done? Is this what was expected?)

In addition to applying different executive and performance processes while actually solving problems, individuals differ in the *learning strategies* they use to acquire new knowledge (Schmeck 1981, and Schmeck and Grove 1979). These strategies for acquiring knowledge have important implications for continuing to learn in a complex, technological society.

Some of these individual differences in cognition have come to be called *cognitive styles*. These cognitive styles seem to develop slowly though experience before becoming automatic ways of processing information, and are not easily altered through education or training (Kogan 1971). Cognitive styles are viewed as high behavior in a variety of situations (Lawson 1984).

Many dimensions of cognitive style have been identified through experimental research. Some of these dimensions seem to control the way individuals receive information, form concepts, retain information, and process information. Table 2 identifies some of the dimensions that seem to affect the learning process most: perceptual modality preferences, field independence versus field dependence, conceptual tempo, and leveling versus sharpening (Keefe 1979).

Cognitive styles comprise one dimension of students' learning styles. Keefe (1979) describes learning styles as "characteristic cognitive, affective, and physiological behaviors that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment" (p. 4). Although often mentioned interchangeably in the literature, cognitive styles and learning styles are not the same. The confusion is greatest when one considers the instruments that might be used to assess cognitive style, because some learning style instruments assess affective or physiological dimensions of learning style rather than cognitive style (Keefe 1982). Table 2 identifies some of the learning style assessment instruments currently available to vocational educators. These instruments can initiate the development of a battery of cognitive assessment devices.

TABLE 2
SELECTED ASSESSMENT INSTRUMENTS FOR EVALUATING STUDENT LEARNING STYLES

Student Learning Style[1]	Assessment Instruments[2]
Cognitive Styles	**Specific**
Reception styles	
Perceptual modality preferences[3]	Edmonds Learning Style Identification Exercise
Field independence vs. dependence[3]	Group Embedded Figures Test
Scanning	
Constricted vs. flexible control	
Tolerance for incongruous or unrealistic experiences	
Strong vs. weak automatization	
Conceptual vs. perceptual-motor dominance	
Conceptual formation and retention style	Cognitive Profile
Conceptual tempo[3]	Gregorc Style Delineator
Conceptualizing styles	
Breadth of conceptualizing	
Cognitive complexity vs. simplicity	
Leveling vs. sharpening[3]	
Affective Styles	
Attention styles	
Conceptual level[3]	Paragraph Completion Method
Curiosity	
Persistence or perseverance	
Level of anxiety	
Frustration tolerance	
Expectancy and incentive styles	
Locus of control[3]	I/E Scale
Achievement motivation[3]	
Self-actualization	
Imitation	
Risk taking vs. cautiousness	
Competition vs. cooperation	
Level of aspiration	
Reaction to reinforcement	
Social motivation[3]	
Personal interests	
Physiological Styles	**General**
Masculine-feminine behavior[3]	Learning Style Inventory (Dunn and Dunn 1978)
Health-related behavior	Cognitive Style Mapping
Body rhythms	Myers-Briggs Type Indicator
Need for mobility	
Environmental elements	

[1] Student Learning Style Model developed by Keefe (1982).

[2] These and other instruments are described in a National Association of Secondary School Principals (1982) publication.

[3] Styles with the greatest implication for improving the learning process are discussed by Keefe (1982).

Intelligence: Modifiable Thinking and Learning Skills

The examination of the cognitive components of problem solving and intelligent performance has led to a new view of intelligence. This new perspective conceptualizes intelligence as a set of thinking and learning skills that can be modified; it differs from the concept of intelligence as a stable, fixed factor or factors (Brown and Campione 1982; Detterman and Sternberg 1982; Glaser and Pellegrino 1982; Resnick 1976; Sternberg 1984; Wagner and Sternberg 1984). As illustrated in figure 5, there has been a shift away from a focus on intelligence tests to the cognitive processes underlying the tests and educational performance (Detterman and Sternberg 1982; Kirby 1984; Resnick 1976). Attention is being given to the processes involved in problem solving (Greeno 1978) learning-to-learn skills (Brown, Campione, and Day 1981; Glaser and Pellegrino 1982), and metacognitive executive processing (Detterman and Sternberg 1982; Sternberg 1984), including self-management or self-monitoring skills (Belmont, Butterfield, and Ferretti 1982; Brown 1978; Brown, Campione, and Day 1981).

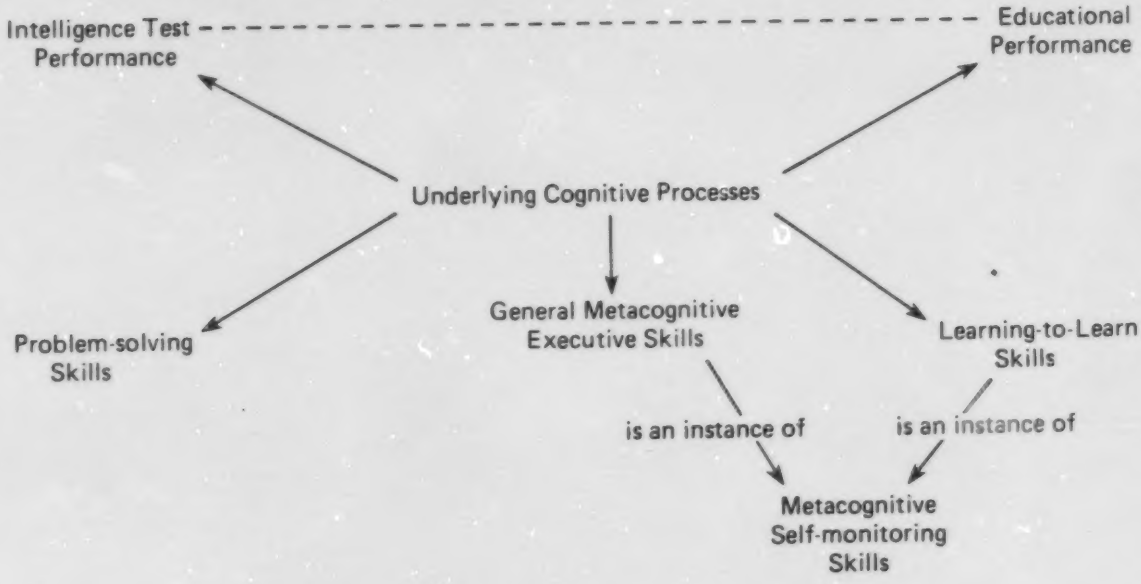

Figure 5. Individual difference and cognitive processes

SOURCE: Adapted from Kirby (1984) and Lawson (1984).

The typical, psychometric view of intelligence as "what intelligence tests measure" does not help educators know how to improve intelligence. However, when the underlying processes of intelligent behavior are identified, vocational and other educators can use these processes as a basis for curriculum and instruction. Educational objectives can guide the development of intellectual and knowledge acquisition skills, as well as learning skills and metacognitive, self-control strategies (Wagner and Sternberg 1984). Training strategies can also be developed (Brown and Campione 1982; Wagner and Sternberg 1984).

Definitions of intelligence have been rooted in the history of testing and school placement practices. The primary goal of this psychometric perspective was to measure intelligence for predicting school performance. This goal has been achieved very successfully by differential or correlational psychology, yet the basis for the technically sophisticated intelligence tests and differential aptitude tests has been unclear (Resnick 1976). In the last 10 years, beginning with a conference in 1974, psychometricians and cognitive psychologists have begun to collaborate on identifying the basic processes that underlie intelligent performance (Carroll and Maxwell 1979; Kirby 1984; Resnick 1976).

Although some educators are enthusiastic about the progress being made toward teaching intelligence (Whimbey and Whimbey 1975), cognitive researchers generally see themselves as being in the early stages of efforts to understand and assess the modification of intelligence (Brown and Campione 1982; Detterman and Sternberg 1982; Glaser and Pellegrino 1982; Wagner and Sternberg 1984). Brown and Campione (1982) feel that it is an overstatement to say that researchers are in the early stages of this endeavor. Most efforts are focused on examining cognitive processes within highly specified domains, not on a global theory of intelligence and its modifiability (Brown and Campione 1982; Detterman and Sternberg 1982).

Learning: Constructive, Adaptive Action

The most persuasive new concept evolving from cognitive psychology is the notion advanced by Wittrock (1974; 1978; 1979a; 1979b) that learning is a generative process; knowledge and understanding are "constructed" by individuals as they process information from the environment as well as from their distinctive memories of previous experiences and semantic schemata. During the perception process, as noted, individuals "fill-in" missing information and construct a representation of reality from well-structured or ambiguous situations.

Memory and understanding are enhanced when students actively construct representations of the information being learned. When faced with learning new information, students attempt to organize the new information by grouping words into conceptual categories or lists of similar sounds, by alphabetizing, or by making idiosyncratic associations—indeed, by using any means that makes the information easier to recall (Glass, Holyoak, and Santa 1979). Several semantic elaboration studies (Bower and Clark 1969) illustrate the importance of students themselves constructing meaningful representations of the information to be learned. Students who were asked to *create a story* as an aid to recalling 120 words recalled 93 percent of them, but a rehearsal group recalled only 13 percent. In another study, students who were told to *form a visual image* of two objects interacting in some way in order to learn 30 pairs of words recalled 87 percent of the words. In the same study, a second group was told to create sentences using the pairs of words. This group recalled 77 percent of the words, as opposed to a rehearsal group that recalled 37 percent of the same words.

In other studies (see Horton and Bailey 1982; Glass, Holyoak, and Santa 1979), the imagery strategy was very effective in improving memory when free recall of information was needed. However, when the recall of information was cued—that is, students were told to generate associations of the cue words from their original word list—instructions to form interactive images hindered recall. It is possible that the context of imagery created by the student with the help of associations provided potential cues for recall but could not be used in the cue recall situation, thus making the words inaccessible. This obstacle might be overcome by using a variety of different study methods to ensure a flexible encoding of information (Glass, Holyoak, and Santa 1979).

Other verbal elaboration strategies that may be used (and are known to be effective) in facilitating memory include underlining words in the text that have been selected as significant by the learner (Rickards and August 1975), generating paragraph headings and summary sentences (Wittrock 1974), and chunking—organizing input items into larger units (Glass, Holyoak, and Santa 1979). Generating hierarchical outlines or networks and extracting general rules are helpful encoding strategies as well as problem-solving strategies. Through these and other processing-learning strategies described by Schmeck, Ribich, and Ramanaiah (1977) and Schmeck and Ribich (1979), students can be helped to learn. Through these active processes, cognitive structures (schemata) are constructed and then stored for use in comprehending and interpreting future information, solving problems, and making decisions at a later time.

When solving problems, people actively interpret the problem before beginning to work and invent problem-solving procedures as needed (Brown and Burton 1978; Mayer 1983; Simon 1980). Faced with problems and limited data, people "seek sensible solutions within the limits of their knowledge" (Resnick 1983, p. 25). This is illustrated by the procedures children create to solve mathematics problems. Brown and Burton (1978) found that children's errors on slightly more complex arithmetic tasks were not factual errors but procedural errors. "Buggy algorithms" (flawed rules) were systematically created and applied by children, presumably using and adapting rules learned earlier. Analysis of sample buggy subtraction algorithms, as in figure 6, illuminates the sensible, rule-driven character of human behavior and the ability of children to generate coherent rules to solve problems. Although some creative solutions may be successful in solving problems, some may not be so successful, as the buggy algorithms demonstrate.

Thus, even without direct instruction, students invent their own rules and conceptions of content. This inclination to invent has both advantages and disadvantages. On the one hand, routine procedures and concepts are learned that are difficult to teach directly; on the other hand, misconceptions of content and "buggy" rules can also result. This disadvantage of invention calls for corrective feedback throughout learning and the need for teachers to look below surface answers and conclusions to the rules and concepts guiding student actions. Correcting incorrect answers is likely to be ineffective unless the instructor also identifies and corrects the faulty rule being followed.

Often teachers will complain: "Look at this! The same mistake again! I tell them what to do, but they never learn!" The reason the same mistake appears again is clearly because the same incorrect rule has been used.

Learners: Controllers of Learning Behavior

In light of the new view of learning as an internal, cognitively mediated process, the locus of responsibility shifts from external reinforcement and instructional prompts to the learner's cognitive processes, motivations, and value systems. Consequently, the notion that learners determine what they learn—along with other learning outcomes—is another new concept that has the potential to revolutionize curriculum design and instructional practices. This is what Wittrock (1979a) has called the principle of individual responsibility.

In research on locus of control, deCharms (1972, 1976) found that achievement in class could be increased if students believed they could influence their performance in school by their efforts. Applying this concept, it was found that, after training, students had not fallen further behind National norms on standardized tests, but had instead significantly reversed the expected trend and remained at a significant 6-month advantage in grade placement a year after training was terminated. Owie (1983) found a definite relationship among

143 −28 125	The student subtracts the smaller digit in each column from the larger digit regardless of which is on top
143 −28 125	When the student needs to borrow, he adds 10 to the top digit of the current column without subtracting 1 from the next column to the left.
1300 −522 878	When borrowing from a column whose top digit is 0, the student writes 9 but does not continue borrowing from the column to the left of the 0.
140 −21 121	Whenever the top digit in a column is 0, the student writes the bottom digit in the answer: i.e., 0 − N = N.
140 −21 120	Whenever the top digit in a column is 0, the student writes 0 in the answer: i.e., 0 − N = 0.
1300 −522 788	When borrowing from a column where the top digit is 0, the student borrows from the next column to the left correctly but writes 10 instead of 9 in this column.
321 −89 231	When borrowing into a column whose top digit is 1, the student gets 10 instead of 11.
662 −357 205	Once the student needs to borrow from a column, s/he continues to borrow from every column whether s/he needs to or not.
662 −357 115	The student always subtracts all borrows from the leftmost digit in the top number.

Figure 6. Samples of buggy subtraction algorithms invented by children

SOURCE: John Seely Brown and Richard R. Burton, "Diagnostic Models for Procedural Bugs in Basic Mathematical Skills," *Cognitive Science* 2 (1978): 163.

locus of control, instructional style, and achievement. Specifically, higher levels of achievement appeared to have been attained by students who were internally motivated by intrinsic reinforcers.

In a case study of the learning tendencies and processes used by three male students learning genetics in first-year biology, Baird and White (1982) observed that the students showed "impulsive . . . and superficial attention, inappropriate application, inadequate monitoring, premature closure, ineffective eradication of misconceptions or deficient rules, and lacked reflective thinking" (p. 238). Baird and White concluded the following:

- Learning outcome is determined by decisions made by the learner. Decision making is influenced by perceptions and interpretations.
- Inadequate learning is due to inadequate decision making. This inadequate decision making is associated with specific, recurring learning deficiencies.
- Learners are often unaware of their deficiencies. This lack of awareness generates inappropriate attitudes (p. 240).

These conclusions are similar to those of Dansereau (1978): "Even good college students have very little knowledge of alternative learning techniques" (p. 2). After conducting a series of experiments on the effect of *instructional* sequencing on comprehension and retention, Dansereau (1978) also noted that individual aptitudes or strategies or both may be the primary causes of performance differences; that is, ultimately, the cognitive structures or strategies control or determine learning achievement. This view of cognitive processes as mediators of learning is supported by findings from a study of fifth-grade students' reports of attention, understanding, cognitive processes, and affect during mathematics instruction. Peterson and associates (1984) found that these students' reports of cognition were more valid indicators of classroom learning than observers' evaluations of their time spent on task. In addition, students' own reported affect as well as cognitions seems to mediate the relationship between instructional stimuli and student achievement and attitudes. These findings suggest that students might be taught the mediating cognitive processes or elaborating techniques that contribute to successful performance of a particular task or perhaps instructional strategies adapted to maintain the mediating cognition. This attention to cognitive differences in learners during instruction has revolutionary implications for vocational education.

Cognitive Task Analysis Tools

New analysis tools unavailable to earlier psychologists have helped answer questions about how cognition influences behavior. These methods provide a way to (1) describe intangible cognitive processes and structure and (2) illumine cognitive processes and knowledge structures needed for intelligent behavior.

The new cognitive analysis tools most likely to be useful to vocational educators include novice-expert analysis and protocol development in addition to cognitive representation methods. Curriculum planners can use these methods to identify and represent cognitive structures and processes used by novice students and those structures and processes mediating the performance of experts. These techniques appear to be useful as general teaching and learning strategies.

An example of these techniques in action will illustrate their potential for use in a vocational program.

Expert technicians were asked to verbalize their procedures during normal repair of the variety of electronic instruments used by a nuclear research establishment

(Rasmussen and Jensen 1974). The men were asked to relax, tell what they were thinking, feeling, and doing, and express themselves in everyday terms including short hints in fast work sequences. A tape recording was made while each man thought out loud. *A protocol* was prepared and reviewed with each technician to clarify unclear aspects of the verbalization. Then these records were coded as a *flow diagram* showing the interconnection of the subroutines.

For educational purposes, these flow diagrams could suggest content to be taught, such as the most successful search routines (e.g., topographic search, functional search, and evaluation of fault) and conditions encountered and the successful action, for example, (1) low bias voltage—correct short circuit in transistor, or (2) faulty triggering of flip flop—replace trigger diode when "blown." (Combinations of such condition-action pairs are called a *production system* in artificial intelligence programs. Powerful, applied, artificial intelligence programs have been constructed that embed almost all the knowledge needed in these production systems.)

In addition, a *network schema* could be developed by teachers, students, or the technician to illustrate the knowledge needed to conduct various searches for different instruments and details to check for specific instruments.

As illustrated by this example, novice-expert analysis can be combined with cognitive representation techniques to learn more about the knowledge and procedures needed for a complex task. All these techniques can be used as teaching and learning tools.

Novice-Expert Analysis and Protocol Development

Bloom and Broder (1950) analyzed the mental activities of college students who had high or low academic aptitudes. Each student was asked to think aloud while solving a problem. This novice-expert analysis technique was used by Ernst and Newell to develop one of the earliest and best-known computer simulations of intelligent functioning, the General Problem Solver (GPS) (Mayer 1981). The technique involves the introspective analysis of cognition by novices and experts as they solve a problem or perform an important task. This cognitive analysis is an important contribution to the task analysis used by vocational educators and curriculum planners. Using this technique, individuals having various levels of expertise attempt to solve a problem or perform a task. Novices (beginning students or those experiencing trouble) and experts (advanced students, teachers, or masters in their field, such as accountants, top salespersons, or chefs) are asked to "think out loud," and tell what is going on in their heads as they solve a specific problem. From this introspection and reporting, protocols describing knowledge and procedures used in solving the problem are prepared.

Cognitive Representation Techniques

Networks, production systems, flowcharts, and programs are major ways cognitive psychologists represent the knowledge and workings of the mind (Lachman, Lachman, and Butterfield 1979). Two types of knowledge can be represented by these methods—factual or conceptual and procedural. Factual or conceptual knowledge and its structure are most often depicted as a network; procedural knowledge is represented by production systems, flowcharts, and programs.

Semantic Networks

With semantic networks, cognitive scientists represent databases or cognitive structures—the elements of a person's or a computer's knowledge base and relationships among those elements (Lachman, Lachman, and Butterfield 1979; Mayer 1981). Such a network representation of a portion of

food service content is shown in figure 7. (This network could compare with the network representations of this same content by students.)

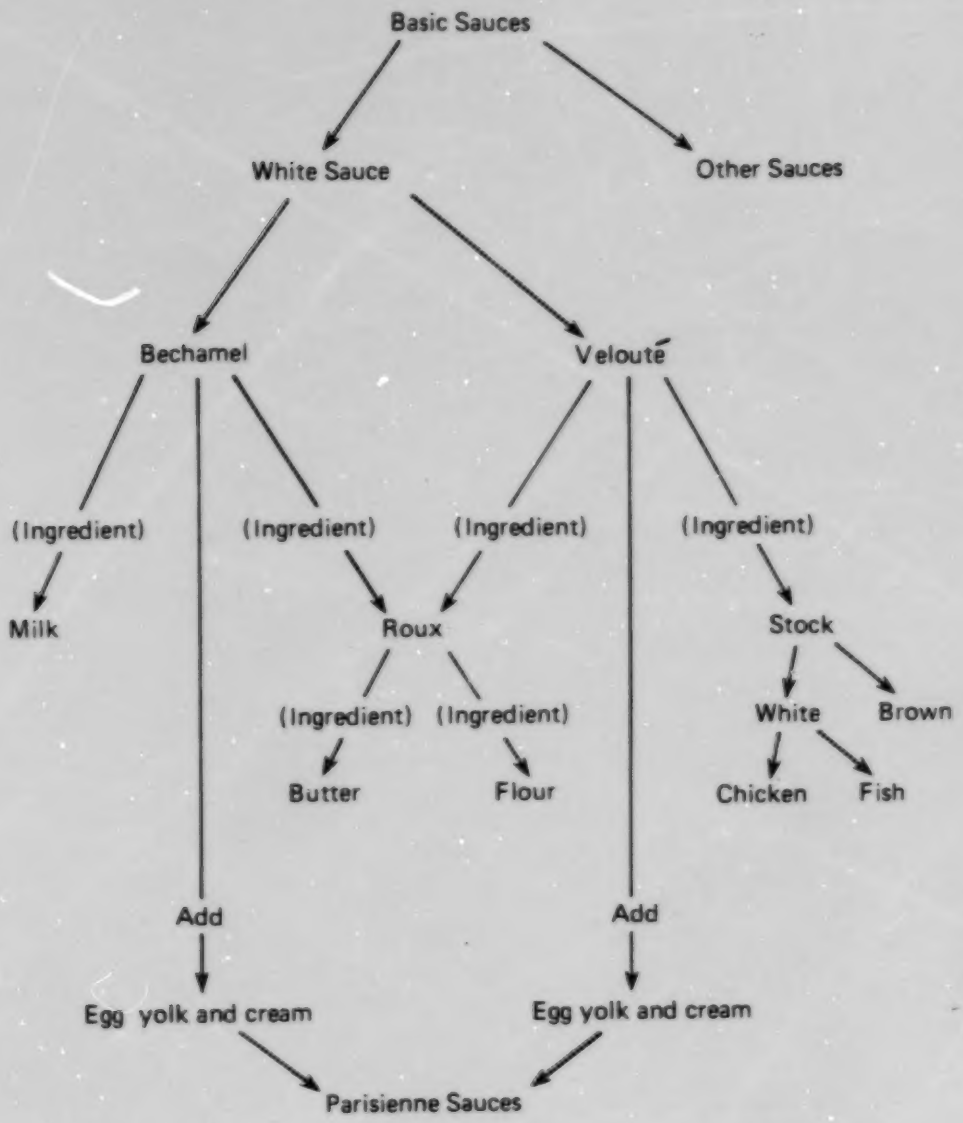

Figure 7. A network representation of content from a food service program: White sauces and variations.

In this typical network diagram, the major elements are represented by words, but pictures or symbols may also be used (Glass, Holyoak, and Santa 1979). Major elements, or nodes, can be represented by ovals, circles, or other graphic symbols, or simply by words, as illustrated in figure 5. Relations between elements are represented with lines and words or abbreviations. Strength of association between concepts may be represented by the length of lines and may be the organizational principle (Lachman, Lachman, and Butterfield 1979).

Cognitive elements can be represented by a spreading network or a tree-like diagram to show a hierarchical organization that begins at the top, branches to a second level, then to a third, and so on. Elements at the top of the diagram are usually more encompassing and flexible than those at the bottom of the tree. Like flowcharts, programs, and spreading networks, "trees" can be created by a curriculum developer or student through observations or interviews. Tree diagrams, like other representation techniques, can then be used to verify or expand understanding about the organization of knowledge and processes using this knowledge in the brain. (See Bourne, Dominowski, and Loftis [1979]; Lachman, Lachman, and Butterfield [1979]; and Mayer [1981] for variations of this technique.)

Networking diagrams can be effective teaching and learning techniques. They can be graphic organizers for reading materials, lessons, units, or programs (Hawk and McLeod 1984). Students or teachers can create networks from readings, demonstrations, or an analysis of an expert's cognitive structure while performing a task or solving a problem. In addition, students' cognitive structures can be evaluated by having them create a network diagram before, during, and after a learning unit.

Production Systems

Whereas factual or conceptual knowledge can be represented by networks, procedural knowledge can be written in terms of "productions," units consisting of an action and a condition specifying when action is taken (Larkin 1980; Newell and Simon 1972; Simon 1980). According to computer-implemented models of memory, the human mind stores an immense number of condition-action units. Whenever a situation arises that meets one of the conditions in memory, the corresponding action is implemented. A simple example is when the condition of a ringing telephone exists, then action is taken to answer it. General condition-action production that may need to be taught in vocational education includes the following:

- If you are ill and must be absent from the job, call your job supervisor.
- When a computer disk is full, transfer a file to another disk to make room in the file being used.
- When learning a new job, compile job responsibility procedures into functional units, or condition-action unit(s).

Condition-action charts may also be developed by students to summarize the procedures needed for solving domain-specific problems. Such a chart might include the name of the procedure, condition to be experienced, and the action or actions to be taken (see Mayer 1981). In addition, relationships among productions can be illustrated with a network diagram of the interactions (Greeno 1978).

Flowcharts and Programs

Flowcharts and programs are used to represent simple and complex cognitive processes and strategies (Mayer 1981). Details

of specific cognitive procedures (i.e., processes and strategies) are graphically illustrated using flowcharts. Such a protocol of an interviewer ("I") with an inventive 5-year-old boy ("B") is illustrated as follows:

- I: "What is 8 take away 5?"
- B: (Puts up 5 fingers, then 6 fingers) "1."
  (Puts up 7 fingers) "2"
  (Puts up 8 fingers) "The answer is 3."
- I: "How did you know the answer is 3?"
- B: "Umm . . . I counted!"

From a protocol such as this, a flowchart or program, such as those in figure 8, can be created to depict the processes or strategies used. With such a technique, vocational students and instructors can focus on procedures used and compare the rules, algorithms, or strategic heuristics applied, rather than on whether or not a correct answer is given (Mayer 1981). Simple models like this can be developed to depict the processes and strategies used by vocational experts and class members to answer a problem, then the procedures can be compared and analyzed.

Farnham-Diggory (1976) sums up the advances in cognitive task analysis methods by saying, "Our modern technological and theoretical capacity to represent *changing conceptual states* is a major advance" (pp. 229-230). These tools for representing knowledge, particularly the development of semantic networks, permit precise and coherent depiction of a discipline's knowledge structures; experts' cognitive structures of knowledge and procedures; students' cognitive structures before, during, and after instruction; and the content structure of learning materials and experiences. Thus, vocational curriculum planners and educators can use these analysis methods for a variety of purposes.

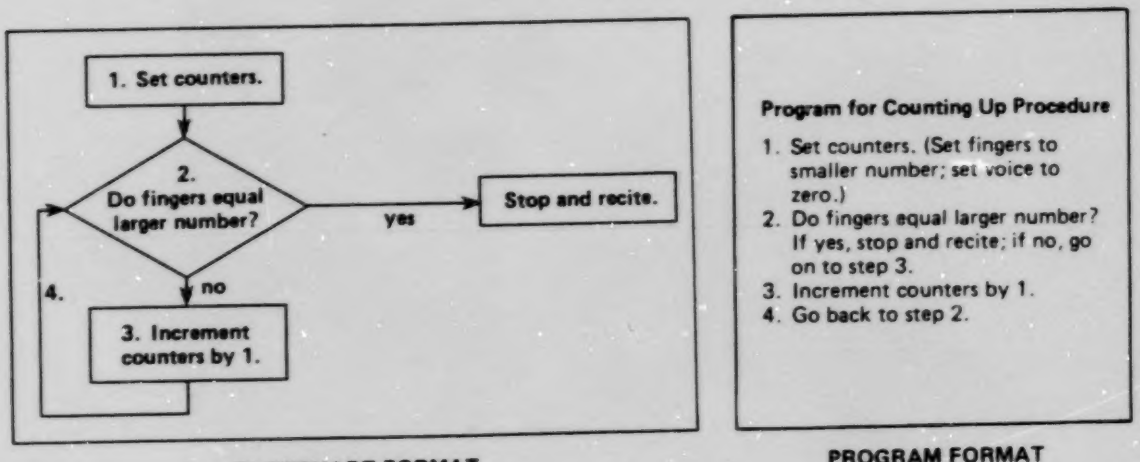
1. Set counters.
2. Do fingers equal larger number?
yes
Stop and recite.
no
4.
3. Increment counters by 1.
Program for Counting Up Procedure
1. Set counters. (Set fingers to smaller number; set voice to zero.)
2. Do fingers equal larger number? If yes, stop and recite; if no, go on to step 3.
3. Increment counters by 1.
4. Go back to step 2.
FLOWCHART FORMAT
PROGRAM FORMAT

Figure 8. Process models for simple subtraction

SOURCE: Used with permission of W. H. Freeman and Company, from Mayer (1981, pp. 44-45).

IMPLICATIONS FOR CURRICULUM AND INSTRUCTION IN VOCATIONAL EDUCATION

What do these advances in cognitive psychology mean? What are the implications for instruction in vocational education? Specifically, how can vocational educators help their students prepare for the uncertain and constantly changing workplace—both as entry-level employees and throughout their careers?

At this time, more is known about the type of cognitive knowledge and processes or strategies needed for expert problem solving than about the specific knowledge and thinking skills needed for vocational success in various occupational clusters. Since cognitive psychology and cognitive science are our sources for information about the cognitive system and are descriptive and not prescriptive sciences, it is not surprising that more is known about *what* knowledge and skills might be taught than *how* best to teach these skills. However, some progress is being made toward this goal, especially through instructional psychology and educational research using a cognitive focus. Recently, theories and research findings from cognitive psychology have been reviewed in educational literature and implications drawn for educational practice in general (Calfee 1981; Doyle 1983; Frederiksen 1984; Posner 1978; Wagner and Sternberg 1984). Military training programs are already applying principles of cognitive psychology to instruction (McCombs 1984; O'Neil 1978; O'Neil and Spielberger 1979; Wittrock 1979a). With some success, educators have designed programs to develop thinking skills (Feuerstein et al. 1980; Whimbey and Lochhead 1982).

Consequently, recent advances in cognitive psychology provide some suggestions for what and how vocational educators should teach. Although more basic and applied research is needed, especially for full-scale evaluations involving vocational teachers and students in real classrooms, there are some implications for instruction in vocational education.

These implications will be presented in two parts. Implications for *what* vocational educators should teach are described in the first part, and implications for *how* vocational educators might teach are outlined in the second part. Empirical evidence supporting these implications for instruction varies. Most can be supported by evidence from experiment or observation, but few have been tried in classroom instructional situations. Some are little more than speculation, even though there seem to be strong arguments for their use.

What to Teach: An Integrated Knowledge Base and Thinking and Learning Processes

An integrated knowledge base and thinking and learning processes should be explicated and taught in vocational education.

The idea that both extensive specific knowledge and thinking skills—cognitive processes—are needed for reasoning and problem solving has resulted from recent work on problem solving done in knowledge-rich domains such as chess, physics, and radiology (for descriptions of such examples, see Glaser and Pellegrino [1982]). This research has shown "strong interactions between structures of knowledge and cognitive processes" (Glaser 1984, p. 97).

Dimensions of an integrated knowledge base and the range of thinking skills that have been identified as important for problem solving and learning are represented in figure 9 and described in more detail as follows.

Integrated Knowledge Base

An integrated knowledge base of concepts, procedures, and patterns of conditions requiring action should be taught in vocational education.

Judging from research on expert and novice problem solvers, process analysis of aptitude and intelligence, and developmental studies (see Glaser 1984), problem solvers cannot be produced in vocational education without building extensive retrieveable knowledge. "All problem solving, comprehension, and learning are based on knowledge" (ibid., p. 100), even if only in the form of general strategies for analyzing situations and attempting solutions (Greeno 1980). The difference between individuals who vary in their ability to think and solve problems is their possession and use of an organized body of conceptual and procedural knowledge (Glaser 1984). In addition, helping students develop an integrated knowledge base is important for acquiring new knowledge, for modifying old knowledge, and for solving problems (Greeno 1978; Norman, Gentner, and Stevens 1976; Myers et al. 1984). Also, this appears to be a prerequisite for thinking (Glaser 1984). An accessible and usable knowledge base is an integrated knowledge base—an interconnected network of relationships among concepts and procedural knowledge. Such a knowledge base is thought to facilitate memory search without interference and loss of time (Myers et al. 1984).

Forming such an integrated knowledge base is most important for transfer and use of knowledge from a cognitive perspective. For cognitive psychologists, the key to transfer lies in the structure of knowledge (Bruner 1963)—the interactions and interrelationships among chunks of knowledge, or networks. These interrelationships among coherent chunks of conceptual and procedural knowledge create even larger chunks of knowledge. The advantage of all this chunking seems to lie in the notion that chunks of knowledge—or schemata—can be set aside in memory, freeing the individual to pay attention to other tasks, to solve other problems (Calfee 1981). Furthermore, these schemata can be used quickly and easily to solve problems, especially if relationships are established by the learner while learning the information.

Vocational education students would probably benefit from developing a hierarchical and interrelated arrangement of core generic concepts, procedure knowledge, and condition patterns for use in the vocational area. These knowledge base dimensions would probably be most useful with core concepts, procedures, and condition patterns arranged hierarchically in that order around major problems of the vocational area (Willems 1981). Such a modifiable information structure, representing generic concepts stored in memory (a schema), would be expanded, revised, and combined with other schemata for use in thinking through and solving problems in a variety of settings.

Generic Core Concepts

Generic core concepts and their relationships to other generic concepts students hold should be taught in vocational education.

Generic core concepts—meaningful, semantic knowledge abstractions—are assumed to be needed for problem solving in each vocational area. Support for teaching core concepts comes from novice-expert problem-solving studies. Whereas novices had knowledge that was organized around literal objects given in a problem, experts' knowledge components were organized around abstractions and principles that subsumed these objects. These aspects

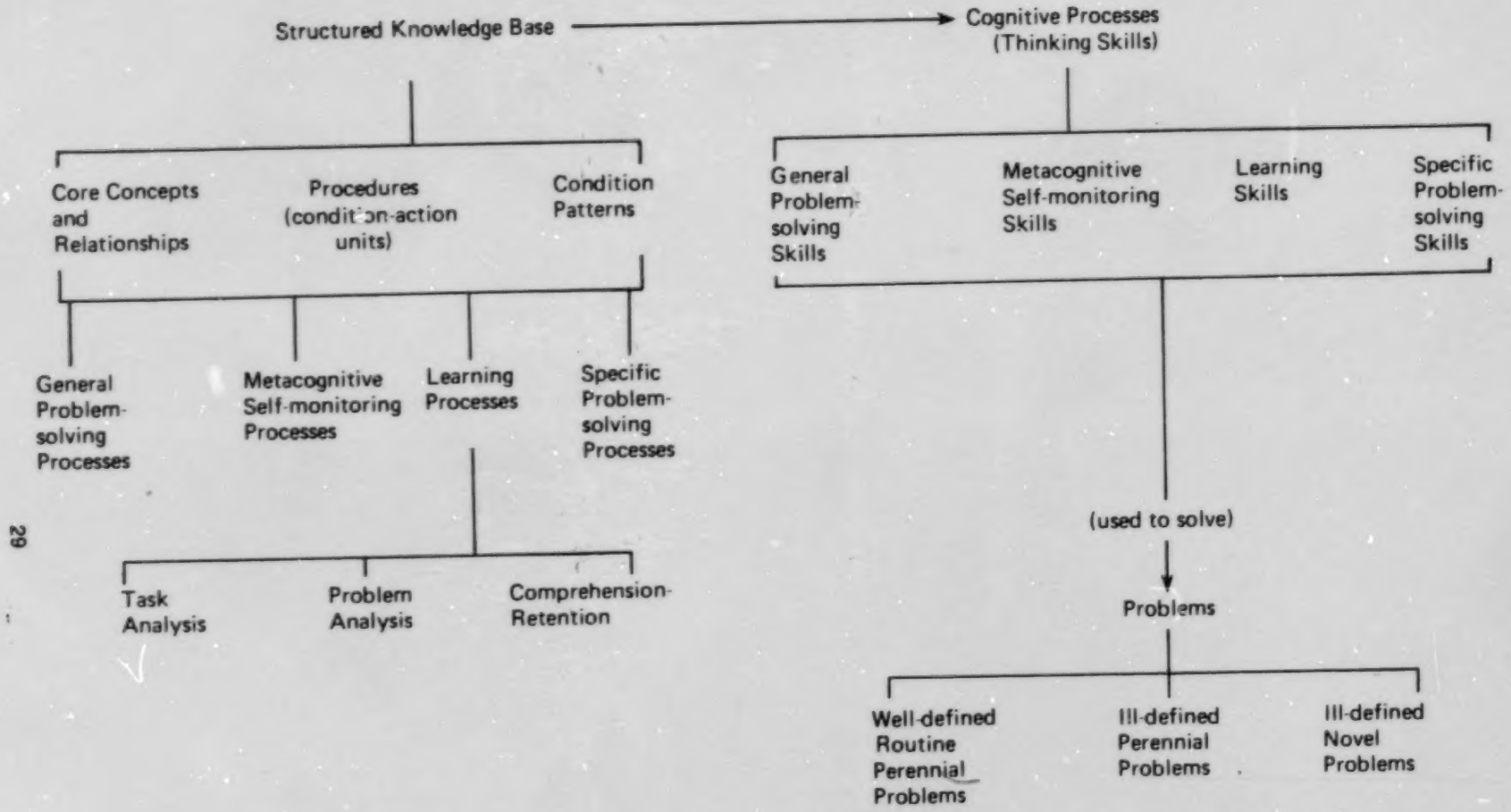

Figure 9. Cognitive components suggested for vocational education curriculum

comprised a tightly connected schema of related principles and their application. For example, generic mechanics concepts that are basic and can be used with concepts from other fields like science or mathematics should be taught in appropriate vocational areas. These mechanics concepts might include mass, position, velocity, force, torque, and interaction laws such as spring and gravitation (Reif and Heller 1982).

Functional, Procedural Knowledge

Procedural knowledge, including general problem-solving, self-monitoring, and learning procedures, as well as specific vocational skill procedures, should be taught in vocational education.

Employers, parents, and educators have high expectations for vocational program graduates. Vocational students are expected to develop specific vocational skills and vocational educators teach them these skills. Other expectations are held for students, as Norman (1980) points out:

> It is strange that we expect students to learn yet seldom teach them anything about learning. We expect students to solve problems yet seldom teach them about problem solving. And, similarly, we sometimes require students to remember a considerable body of material yet seldom teach them the art of memory. It is time we made up for this lack. (p. 97)

Vocational students, like all students, need to learn how to solve problems, to learn, and to remember, and vocational educators need to teach these procedures and skills to help students continue learning and solving new problems throughout their careers. For some low-achieving vocational education students, having these skills may make the difference between their achieving and not achieving. Wittrock (1979b) supports the need to combine general education and literacy training with technical job training by noting that "especially with marginally literate people, some of these generic skills may not be well developed" (p. 313). He goes on to say:

> A program that combines development of generic cognitive skills with training of specific job-related skills has advantages for the enhancement of motivation and self-esteem, and for inducing changes in the attribution processes. (ibid.)

McCombs (1984) found that military service personnel did in fact benefit in these ways from such an integrated program.

Rules or algorithms needed for knowing what to do, what action to take when certain conditions are present, are necessary for intelligent problem solving (Glaser 1984; Simon 1980). This procedural knowledge might be expressed in terms of condition-action pairs in production units; these units are then combined into production systems. These rules may be stated in the form of condition-action statements (J. R. Anderson 1980; Simon 1980): IF . . . condition(s) . . . THEN . . . take . . . action.

Four different types of procedural knowledge should be taught vocational education students:

- General problem-solving procedures called strategies, heuristics, or plans
- Specific vocational problem-solving procedures
- Learning procedures
- Self-monitoring procedures

General problem-solving procedures seem most useful for novel situations, ill-structured problems, or problems requiring knowledge that is not yet known or is only sketchy. As Simon (1980) observes:

> Bare facts, however they are stored in memory, do not solve problems. . . . Powerful general (problem-solving) methods . . . exist and . . . they can be

> taught in such a way that they can be used in new domains where they are relevant. (pp. 85-86)

He goes on to say:

> General problem-solving techniques . . . are likely to play an essential role whenever (a skilled person) has to move into new territory and attempt new learning. (p. 91)

Examples of these general, metacognitive, problem-solving procedures include planning procedures, such as means-end analysis, hypothesize and test, Simon's (1980) best-first search, verbalization of goals and strategies, Resnick's (Klahr 1976) feature detection by scanning the task situation, and representation procedures such as using analogies (see Glass, Holyoak, and Santa 1979; Reed 1982). Other metacognitive procedures, the principal abilities underlying intelligent behavior, are identified by Sternberg (1984) and Feuerstein et al. (1980) (see table 1).

Specific problem-solving procedures are used for well-structured problems in specific domains such as a particular vocational area (e.g., rules of sanitation in cosmotology: if comb or brush falls on the floor, then . . .). Whereas Simon (1980) argues for teaching general problem-solving procedures, Norman (1980) and Greeno (1980) believe that specific knowledge for a category of problems is more important than general strategies, although general problem-solving procedures are viewed as probably more transferable (Greeno 1980; Simon 1980; Sternberg 1984).

Learning procedures—strategies for acquiring, retaining, and retrieving different kinds of knowledge—are seen as promising for "facilitating the effectiveness of education and training programs" (O'Neil and Spielberger 1979, p. xi). Whereas academically motivated and high-achieving students tend to use appropriate learning strategies, poorly motivated and low-achieving students do not seem to use appropriate learning strategies (Biggs 1984). Even "good" college students are not aware of alternatives for varying learning tasks (Dansereau 1978).

There is some evidence that especially low-achieving and low-motivated students should be taught learning strategies and will achieve more successfully and be more satisfied with their performance after learning strategies training (Biggs 1984; McCombs 1984). In general, learning strategies and their use should promote personal control of learning (McCombs 1984) and consequently reduce feelings of helplessness.

Cognitive task analysis, condition-action rule development, problem analysis, and comprehension-retention-retrieval learning procedures have the potential for helping vocational students learn how to learn. The constructive, processing nature of both cognitive task analysis and condition-action rule development may be appropriate learning strategies for helping vocational students explicate the condition-action rules needed for solving problems or performing tasks expertly. By observing and interviewing expert employees, novice employees could use the condition-action rules being used by experts to solve on-the-job problems or to create their own procedures from analyzing tasks to be done.

Metacognitive, self-monitoring procedures should be explicated and taught. Reasons for explicitly teaching self-monitoring procedures are compelling:

- Metacognitive skills are important in intelligent cognitive performance (Brown 1978; Wagner and Sternberg 1984).
- Students, especially young and less-able students, seem to have inadequately developed metacognitive

skills (Brown 1978; Wagner and Sternberg 1984). For example, students have been shown to—

—be unskilled in predicting task difficulty;
—be insensitive to incomplete or incomprehensible directions, written information, or verbal communication;
—have difficulty planning ahead and allowing adequate time for study; and
—have difficulty predicting their own performance.

- Metacognitive skills are presently not being taught in most curricula (Wagner and Sternberg 1984).

Although there is a need to teach metacognitive skills, particularly the self-monitoring skills, there is little consensus as to which specific skills to teach. Rigney's set of self-monitoring skills is a starting point. These skills seem to reflect specific ways students can use what Bloom and Broder (1950) and Whimbey (1984) describe as *precise processing*. These educators see precise processing as the key attribute of higher order thinking. Bloom and Broder were first to observe that high-aptitude students were active in their attack on problems, often using a lengthy step-by-step analysis to arrive at an answer. These students carefully proceeded, using their information to clarify the question further. In contrast, low-aptitude students used *one-shot thinking*. Their problem solving involved superficial and careless thinking, often selecting a solution on the basis of a few clues, a feeling, impression, or guess. Similar differences between high- and low-aptitude students at various age levels and across academic areas have been observed by other psychologists and educators (Feuerstein et al. 1980; Whimbey 1984; Whimbey and Lochhead 1982).

Patterns of Conditions

Patterns of conditions requiring action should be explicitly taught in vocational education.

Recognizing a condition needing action requires having patterns of different conditions as a part of a knowledge base. Master chess players were estimated to have 50,000 board configurations (Simon 1980). These configurations, or patterns, evoke successful moves, or actions. Simon believes this perceptual aspect of problem solving deserves emphasis:

> We need to help our students improve their skills of recognition . . . so . . . they [can] recognize rapidly the situational cues that signal the appropriateness of particular actions. (p. 94)

Thinking and Learning Skills

Thinking and learning skills should be developed so vocational students can use their procedural knowledge automatically.

Cognitive skills, or thinking skills in educational terms, appear to develop much like motor skills (J. R. Anderson 1980). Skill learning proceeds through three stages:

- A cognitive state in which the procedure for the skill is learned
- An associative state in which the skill performance method is worked out
- An autonomous state in which the skill is performed more rapidly and automatically, requiring less attention (J. R. Anderson 1980; Posner and Keele 1973)

Having a cognitive skill, or being able to use a procedure automatically, seems to be a

different type of learning outcome from knowing a procedure for a particular situation (Gagne 1984). Students may understand a procedure or rule for action but may not automatically use it. According to Glaser (Klahr 1976), unless cognitive procedures are automatic in their use, students may be "in the position of a centipede who analyzed the processes by which he moved his hundred legs, and became incapable of walking" (p. 307). As J. R. Anderson (1980) points out, different procedures, like different concepts, can help or interfere with one another. Furthermore, new strategies may take up resources that would be used for aspects of problem solving, thus interfering with performance (Rigney 1980).

Using cognitive processes automatically is a characteristic of experts' superior problem-solving performance. According to Simon (Resnick 1976), when compared to novices, experts do not have to "think about" what to do. They seem to have cognitive skill, that is, an ability to perform various intellectual procedures.

Cognitive or thinking skills vary considerably, ranging from general, metacognitive skills to skills that are very specific to the task or problem being solved (Gagne 1984). Those skills in between appear to be learning skills used to acquire, remember, and retrieve knowledge. They are also needed later to learn new knowledge and skills without having to stop and think about what to do.

How to Teach: Instructional Strategies

Several instructional strategies have been suggested by cognitive psychologists from their experiences with students and others as they have tried to determine how people learn, how they solve problems, and what factors affect these processes. These strategies include using cognitive objectives (not to be confused with Bloom's [1950] cognitive objectives), examples and models, practice with feedback, and a range of direct and indirect discovery strategies, as well as introspection strategies—having students think out loud about their thinking and thinking in general.

Cognitive Objectives

Specifying cognitive skills as explicit cognitive objectives or goals for a course is beneficial.

Focusing instruction and student learning on behavioral objectives is a practice generally accepted by vocational educators that evolved from behavioral psychology. Just as behavioral psychologists feel focusing on changing behavior is beneficial, cognitive psychologists feel focusing on changing cognitive processes or knowledge structure would be beneficial. Citing Larkin and Reif, Cyert (1980) believes that explicit cognitive teaching objectives will benefit instruction, and that these benefits are essentially the same benefits behavioral psychologists see for behavioral objectives:

- Cognitive objectives, according to Hayes (Klahr 1976) focus attention on the underlying cognitive processes and knowledge structures.
- The instructor teaches deliberately toward these goals.
- Students are aware of teacher efforts to orient their learning toward these goals.
- Diagnosis of students' learning difficulties is made easier.

Examples of cognitive goals that could help guide course or program activities include these used by Rubinstein (Tuma and Reif 1980) for his college-level course on general problem-solving skills:

- Develop a general foundation of problem-solving approaches and master some specific techniques.

- Emphasize the thinking processes at all stages of problem-solving activity.

- Identify individual problem-solving styles and learn to overcome self-imposed constraints.

Cyert (1980) implies that these cognitive goals for a general problem-solving skill development course would be appropriate to guide general problem-solving skills development in subject-matter courses. He also suggests his illustrative cognitive goal for subject-matter courses: gain understanding of new relations among concepts and procedures.

The difference between behavioral objectives and cognitive objectives becomes somewhat apparent when comparing the definition of both behavioral objectives and cognitive objectives and some examples of each (see table 3). Behavioral objectives identify a particular set of behaviors we want students to perform after instruction, whereas cognitive objectives state a set of changes in the thinking processes and knowledge structures students use to perform tasks (Greeno 1978). As can be seen from the examples in table 3, cognitive objectives focus on the kinds of knowledge to be gained, that is, patterns of conditions, rules for action, and the thinking processes that would be beneficial to students in solving problems or performing tasks.

Some of these process-oriented objectives may be derived from analysis of the processes underlying intelligent behavior, such as those conducted by Feuerstein et al. (1980), or from analysis of particular vocational education tasks, such as those conducted of bookkeeping and electronic troubleshooting. Additional process-oriented objectives may come from the problem-solving process appropriate for particular types of problems. For example, home economics problems, the what-to-do, practical problems, would be most appropriately resolved using the practical reasoning process (Brown and Paolucci 1979; Laster 1982). Other areas, such as mathematics, have processes that are most appropriate for problems in that area. That process would be taught to help students solve a particular type of problem. In addition, the pattern for identifying that type of problem would also be taught; that is, when you have a what-to-do question that requires action, use the practical reasoning process.

Examples and Models

Information about exemplary concepts, procedures, solved problems, and thinking processes is needed to develop conceptual and procedural knowledge.

Using examples of what needs to be taught has long been an important strategy for developing conceptual knowledge. Examples can be evident in demonstrations, exhibits, and anecdotes. The list is endless. The important idea that cognitive psychologists (such as Bruner and Ausubel) have advanced is that the examples should illustrate the distinguishing attributes or characteristics of a procedure, condition, or concept.

Written examples of individuals solving problems, along with their comments and strategies, are used by Whimbey and Lochhead (1982). The importance of "first-hand, rather than second-hand, experiences" selected to illustrate the distinguishing characteristics of the concept or the condition-action rule and to foster students' constructing their own concept or procedural rule has been emphasized by many (J. R. Anderson 1980; Ausubel, Novak, and Hanesian 1978; Bruner 1963).

One way vocational educators can provide procedural information is through instructional materials that give factual information, together with procedural knowledge. This concept is examined in a study by

TABLE 3
COMPARISON OF BEHAVIORAL AND COGNITIVE OBJECTIVES

Behavioral Objectives	Cognitive Objectives
Definitions	
Set of **behaviors** to be performed by students after instruction	Set of **changes** in students' cognitive processes or knowledge structure
Example of a Routine, Well-structured Problem Problem: What are the causes of a dense and heavy yeast bread product with a pale thin crust?	
Identify causes of food preparation problems. Solve yeast bread preparation problem by describing the ingredients and preparation techniques causing problem when given the characteristics of the final product, the desired characteristics, and ingredients and mixing procedures used.	Acquire rules for identifying yeast bread preparation problems. Recognize pattern of problems in yeast bread products. Add yeast bread components, chemical principles and reactions, procedures, and patterns of problem conditions to memory schema. Use hypothesize-and-test general problem-solving strategy with food preparation problem. Select relevant cues to define problem.[1] Use precision and accuracy in data gathering.[1]
Examples of Creative, Ill-structured Problem Problem: What should be done to coordinate family and career responsibilities?	
Describe changing male-female roles. List the characteristics of a workable work-family schedule. Identify factors that affect coordination problem. Describe alternative strategies for coordinating family and career responsibilities. Define and discuss quality vs. quantity of time spent with family members using data showing the consequences of quality time on the social, emotional, and intellectual development of preschool children. Solve work and family coordination problem when given a case study of a working single parent with children.	Identify and define nature of problem.[2] Use practical reasoning problem-solving process to solve practical problems.[3] Use value analysis technique to evaluate values to be used in making decisions. Use means-end problem-solving procedures.

[1] Objectives are derived from Feuerstein et al's. (1980) analysis of cognitive functions underlying intelligent behavior.

[2] Objectives are derived from Sternberg's (1983) analysis of principal abilities underlying intelligent behavior.

[3] Practical reasoning is the problem-solving process suggested for solving practical, what-to-do problems in home economics (see Brown and Paolucci 1979; Laster 1982).

Larkin (1980). Students were given three versions of instructional materials:

- A conventionally written presentation of factual information and worked examples.
- A conventionally written presentation of factual information, worked examples, and a sequential list of directions.
- An organization of the factual information, worked examples, and directions to encourage students to "collect these directions into functional units of the procedures likely to be applied together, that is, organized into condition-action production units" (p. 121).

Student problem-solving ability was helped substantially by the last type of materials. Evidently, this difference resulted from the active, constructive involvement required of students to compare examples, make inferences, and organize rules for future action. The creation of condition-action rules illustrates one way to encourage vocational students to group or "chunk" information so it is more usable in problem solving.

Practice with Feedback

Practice with appropriate feedback is necessary for developing thinking and learning skills.

The way to acquire expertise is through practice, thousands of hours of practice. Whereas behavioral psychologists have advocated practice for the development of motor skills, cognitive psychologists are just beginning to recognize the importance of practice for the development of problem-solving, thinking, and learning skills.

Practice may be one way knowledge of efficient procedures and higher levels of cognitive skill develop. Through repeated use of the same operations and content, shortcuts and more effective or efficient procedures are discovered (Scardamalia and Bereiter 1983). This may be the way important cognitive skills such as executive decision-making or self-monitoring skills that cannot be explicitly taught are learned.

Range of Instructional Strategies

A combination of direct, indirect, and introspective instructional strategies is necessary to foster the range of cognitive knowledge and skills needed by vocational education students.

Learning and thinking skills develop as learning situations are encountered requiring the use of cumulative knowledge to serve purposes and goals (Glaser 1984). Project-oriented teaching and problem-based teaching (Willems 1981) meet this criterion. In problem-based teaching, students are presented with a range of problems posed for large-group and individual solution. These include well-structured problems clearly describing the problem, criteria, and solution and ill-structured problems not clearly specifying the problem, criteria, or solution.

Direct Instructional Strategies

Procedural knowledge or know-how is normally gained through observation, practice, and rule learning; most intellectual skills are learned this way, whether reading, writing, or solving some problems. But not everyone acquires effective cognitive strategies for basic skills and solving problems, and "normal processes . . . do not appear reliable for acquiring strategies for expert performance" (Scardamalia and Bereiter 1983, p. 63). Only specific vocational skills and some learning skills may be taught directly through rule learning, demonstration-observation, and practice-feedback sequences.

Indirect Discovery Instructional Strategies

Reasons for using indirect or introspective instructional strategies and not using direct instructional strategies for teaching self-monitoring and other metacognitive procedures involved in planning and decision making include these:

- Large-scale metacognitive training may be impractical.
- Effects of metacognitive activities may be reduced when they are externally imposed rather than spontaneously generated by students. (Wagner and Sternberg 1984)
- Often, students who are taught metacognitive self-monitoring strategies seem not to use what they have been taught. (See also Flavell 1976.)
- To be effective, strategies must be so well learned and performed that they do not interfere with actual learning.
- Information about one's own cognitive processing is not easily available to examine, especially when solving a problem or pursuing a cognitive task. (See also Scardamalia and Bereiter 1983.)

Introspective Instructional Strategies

One way to help students improve their cognitive self-monitoring is to give them greater access to information arising from their own cognitive processes. Through some 70 cognitive experiments with young people, Scardamalia and Bereiter (1983) discovered that the children became actively interested in what the experimental procedures allowed them to learn about their mental processes.

Involvement and enthusiasm were generally high and the children enjoyed analyzing the task and the process. From their coinvestigation research experiences with children, Scardamalia and Bereiter do not foresee courses in metacognition being taught, but they do see activities being designed to bring more of the cognitive processes out in the open where teachers and students can examine and try to understand them. They suggest two techniques.

The first is open inquiry about thinking, or general purpose techniques for externalizing cognition. This technique calls for these steps:

- Share purpose for examining cognitive strategies.
- Coexamine thinking processes—share what thinking processes and strategies are being used.
- Have students think out loud while doing a concrete task. (To help students learn to do this, have them practice thinking out loud while doing a nonverbal activity such as drawing a picture.)
- Have students prescribe rather than describe, for example, give advice to another student for carrying out the task.
- Attend to nonverbal cues and use them as points for discussion.

  —Eye shift
  (You just noticed something, didn't you?)

  —Change in rate
  (You're going faster now. Is this part easier?)

  —Discouraged look
  (You look discouraged. Is something particularly hard here?)

  —Satisfied look
  (Did you figure something out?)

—Long pause
(What's going on in your mind now?)

- As you perform a task and describe the cognitive strategy you are using out loud, ask students to evaluate the strategy. Then ask if what you did was anything like what they did. Compare and discuss alternative strategies.

- List the procedures students use and the procedures they do not use. This will help them gain insight into strategic choices related to successful performance.

The second technique is the model-based inquiry, or technique to promote strategy change. This technique involves these steps:

- Facilitate procedural change by providing a task or problem that is new to the students. Have them compare the routine strategies used in normal tasks or problems with the strategies required for this task.

- Use tasks that transfer existing strategies to new domains.

- Have students provide procedural support for others. Give students a list of procedural cues that are more mature or promote more expert performance than the supporting student usually uses.

Suggestions for Curriculum Planners

Here are a few suggestions for curriculum planners:

- Vocational tasks and problems in occupational clusters should be analyzed to determine the knowledge base and thinking skills involved.

- Vocational students' knowledge base and structure for occupational cluster, cognitive processes, strategies, and styles should be assessed before, during, and after instruction.

- Cognitive educational objectives can be derived from cognitive task analyses and student cognitive assessment.

- Curriculum plans should include the knowledge needed to perform critical occupational tasks and solve well-structured as well as ill-structured occupational problems such as the following.

  —General problem-solving procedures for well-structured and ill-structured problems or tasks.

  —Facts and concepts for solving specific problems and performing specific tasks in the occupational cluster.

  —Networks showing the pattern of relationships among facts, concepts, and procedures in occupational clusters and the relationship between occupational networks and other occupational clusters or disciplines. These networks should probably have a hierarchical organization, with functional properties at the highest level and structural properties at the lowest level.

  —Procedural knowledge in the form of condition-action pairs; that is, the rules or algorithms needed for knowing what to do (action), and the patterns of conditions to be recognized for solving occupational cluster problems: IF . . . (conditions) . . . THEN . . . (action to be taken).

- Vocational curriculum plans should include the explicit thinking and learning skills to be developed.
  - —General problem-solving strategies for ill-structured problems without known procedural strategies.
  - —Specific problem-solving procedural strategies for well-structured occupational cluster problems with known procedural strategies.
  - —Supporting cognitive processes needed (but may be missing) to solve particular types of problems.
  - —Learning skills for (1) comprehending and retaining information, (2) using cognitive self-awareness and self-monitoring skills, (3) analyzing tasks for knowledge and skills needed, and (4) analyzing problems for their level of structure.

PROBLEM-SOLVING AND LEARNING SKILLS IN VOCATIONAL EDUCATION

How best to prepare students for successful participation in the workforce of the future is a major question facing vocational educators. For successful employment and upward mobility in our changing workplace, vocational education graduates will need—

- the ability to learn and adapt to changes in the workplace,
- a general education in core competencies including reasoning and problem-solving skills, and
- the ability to participate in cooperative decision making (National Academy of Sciences 1984).

Meeting these needs requires curriculum and instructional planning. One potential source of information for this planning is psychology, particularly cognitive psychology, since its major concern is "understanding the nature of human intelligence and how people think" (J. R. Anderson 1980, p. 3).

Summary of Advances in Cognitive Psychology

A review of the experimental and instructional psychology literature with a cognitive focus and the related cognitive science literature produced these understandings:

- The human cognitive system intervenes between the teaching-learning environment and behavior, controlling learning and problem solving.
- Intelligent problem solving requires extensive, accessible conceptual and procedural knowledge.
- Learning involves combining bits and pieces of information into "coherent chunks" of knowledge that are then combined into network structures of even larger chunks for use in problem solving and future learning.
- Learning is an active, constructive process, rather than a memorizing process, requiring deep, elaborative thinking to create knowledge structures for retention and transfer of knowledge and skill.
- Learners control their learning and behavior with the knowledge structures, thinking skills, and learning skills they possess.
- More-able learners and expert problem solvers have more accessible knowledge and cognitive skills than less-able learners and novice problem solvers.
- Intelligent problem solving involves metacognitive processes, that is, general controlling processes, such as—
  - —planning and decision making,
  - —problem representation, and
  - —self-controlling processes.
- General problem-solving processes, such as planning, decision making, and problem representation skills, seem important for solving—
  - —novel problems,
  - —ill-defined problems, and
  - —problems when the problem solver has little or no conceptual knowledge about the problem.

- Self-monitoring skills seem important for learning and solving all types of problems well.

- Cognitive knowledge structures and processes can be identified through—

  -introspection (thinking out loud) and
  -inquiry by a teacher, parent, or peer about the thinking or learning processes being used.

- Cognitive knowledge structures and processes can be specified and represented with semantic network diagrams, production systems, flowcharts, and programs.

Implications for Curriculum and Instruction

These advances in cognitive psychology have implications for curriculum and instruction in vocational education:

- The content of vocational education needs to be expanded to include problem-solving, self-monitoring, and learning skills.

- An integrated knowledge structure, involving generic core concepts, procedures, and condition patterns of general problem-solving, self-monitoring, learning, and specific vocational skills, should be taught.

- Critical problem-solving, self-monitoring, and learning skills should be developed so vocational students can use them automatically to solve problems.

- Conceptual and procedural knowledge of thinking and learning processes can be developed through—

  —exemplary examples, such as demonstrations or written examples;
  —open examination of thinking and learning processes used; and
  —practice with feedback from self-introspection and inquiry about thinking processes from a mediator—a parent, teacher, or peer.

- Thinking and learning processes seem to develop in learning environments requiring use of knowledge to serve a purpose or a goal, such as solving a problem or performing a task. This seems especially likely if students are encouraged or helped to generate an abstraction of the concepts, procedures, or patterns of conditions involved.

Conclusions

The application of cognitive science has potential for helping vocational students develop problem-solving and learning skills needed for successful careers in the workplace. From this review and the reviews of others (see Doyle 1983; Frederiksen 1984; Glaser 1984; McCombs 1984) it would appear that problem-solving and learning skills can take place in subject-matter courses and can benefit students. The extent of potential benefits needs investigation. Vocational education programs would provide an ideal learning environment for developing general problem-solving, self-monitoring, and learning skills. For this to become a reality, the following must take place:

- Vocational educators must have and use curriculum materials that require students to process information to:

  —form concepts, procedure rules, and patterns of conditions needing action and

—practice critical problem-solving, self-monitoring, and learning skills.

- Vocational educators must have and use curriculum materials and experiences that help students develop concepts of and procedures for problem-solving, self-monitoring, and learning strategies.

- Vocational educators must provide firsthand experiences with employment problems and tasks and capitalize on these experiences by helping students develop concepts and procedures from those experiences.

- Vocational educators must serve as mediators for students as they think about thinking and the processes they use that are both successful and unsuccessful. In doing this, they might—

  —coexamine thinking processes—their own and their students' thinking;
  —attend to verbal and nonverbal cues encouraging students to be cognizant of their processing;
  —provide tasks and problems that challenge students to develop a variety of thinking and learning skills for expert performance;
  —teach underlying cognitive abilities fostering success on vocational tasks or problems. (See Feuerstein et al. 1980.)

In order for vocational educators of high school and adult students to provide this kind of learning environment, they will need educational experiences that will help them do the following:

- Understand the human cognitive system, its limitations and capacity

- Identify and represent cognitive structures and processes

- Understand the learning process from a cognitive perspective and ways this process can be enhanced in the classroom

- Create learning experiences and materials that will facilitate the development of learning, thinking, and knowledge structures for problem solving and future learning

- Use evaluation procedures for identifying and evaluating the knowledge structures and processes used by students

- Have a model for identifying cognitive deficiencies

Although progress has been made, there are still many gaps in our understanding of cognitive psychology and how knowledge in this area can benefit curriculum planning. Following is a synthesis of what we do know and areas that need further research.

- Through cognitive psychology and science, progress is being made toward understanding the cognitive process and knowledge structure dimensions needed for learning and problem solving.

- Some progress is being made toward knowing what kind of instructional procedures will help students develop the knowledge base and automatic processing needed for cognitive skills.

- Although progress is being made toward identifying the cognitive components of reading, mathematics, and science tasks (Resnick 1981, 1983), almost nothing is known about the specific cognitive processes involved in solving vocational tasks. (The bookkeeping task [Dillard, Bhaskar, and Stevens 1982] and electronic troubleshooting [Rasmussen and Jensen 1974] have been analyzed.)

- Although metacognitive skills such as planning, decision making, problem representation, and self-monitoring are deemed important, little is known about which processes are used in solving different types of problems or the instructional strategies most appropriate for teaching these processes (Doyle 1983).

- Instructional approaches for teaching problem-solving skills for well-structured and well-defined problems in narrow domains of knowledge, such as mathematics, are known, but much needs to be learned about how fuzzy or ill-defined problems like those faced in real life are solved and about how to teach students to solve those problems (Frederiksen 1984).

- Despite the hope that instruction could be adapted to individual differences to ensure success, Resnick (1979) notes that efforts toward this end "can only be called primitive . . . [since] we have virtually no tests that have proven practically useful in guiding and monitoring this process" (p. 211).

Recommendations for Vocational Education

A concerted effort should be made to introduce and apply some of the concepts from cognitive psychology and science to vocational curriculum and instruction. Here are several suggestions to achieve this goal:

- Develop a learning and problem-solving strategies curriculum component for integration into high school and adult programs. The components should include cognitive self-awareness and self-monitoring; problem recognition; constructive learning strategies (including deep, elaborative processing strategies) and task analysis; and problem-solving strategies. See table 4 for additional suggestions based on findings from psychological and education research findings.

- Local vocational programs should institute an information processing approach to learning. Tasks should be occupation specific with problems incorporated as a means not an end for learning. Students and instructors should focus on the realities of the work world. This will increase the likelihood of generalizing learning.

- Develop condition patterns and procedure rules for vocational programs. This will help students to process information and form concepts.

- Practice opportunities for solving problems need to be incorporated throughout the vocational program. Opportunities to solve both routine, defined problems and "fuzzy" or novel problems should be systematically incorporated into the curriculum. For example, a small "fuzzy" problem such as that encountered in a new job could be introduced at the beginning of vocational programs, and general problem-solving strategies could be taught to help students solve the problem (see Willems 1981).

- A combination of instructional strategies to help students learn by rule, by discovery, and by reflection should be used throughout the vocational education curriculum. However, direct instruction might be most appropriate for novices and low-ability students, with reflection on their own thinking as an instructional strategy to promote self-monitoring. Problems with uncertain conditions could be introduced as they develop skill, and a guided discovery strategy could be used (Singer 1977).

- Teacher education programs should be provided that assist vocational

TABLE 4

COMPONENTS OF INTEGRATED LEARNING STRATEGIES AND PROBLEM-SOLVING CURRICULUM

Content Components	Suggested Learning Experiences
Cognitive Self-awareness	
Cognitive performance analysis	Develop protocol of self and expert talking aloud about thought processes while solving a problem or performing a task. Compare and contrast two protocols, identifying the condition-action rules used.
Learning style assessment	Examine findings from students' cognitive learning style and learning processes.
Motivation Enhancement (see deCharms 1976; Fiske and Taylor 1984; McCombs 1981-1982, 1984)	
Realistic goal setting Origin vs. pawn training Participatory decision making Team building Achievements and success	Set weekly and daily goals; plan progress check and evaluation. Use quality circle activities (see Lloyd and Rehg 1983).
Cognitive Self-monitoring and Self-management Techniques (see Brown 1978; Rigney 1980)	
Deciding when and how to check Self-testing Self-talk Self-correction	Use direct learning of rules for self-monitoring; use demonstrations and practice with feedback and condition-action rule development.
Pattern Recognition (see J.R. Anderson 1980)	
Problem structure Conditions requiring action	Compare examples of problems being solved and create condition-action rules.
Constructive Learning Strategies (see B.F. Anderson 1980; O'Neil 1978; O'Neil and Spielberger 1979; Schmeck and Grove 1979)	
Deep-processing strategies (e.g., comparing, contrasting, evaluating)	Practice with feedback; introspection.

TABLE 4—*Continued*

Content Components	Suggested Learning Experiences
Verbal elaboration strategies (e.g., underlining important words, generating headings, paraphrasing, networking, imagery, question asking, summary sentences, chunking, and creating examples) Condition-action rule development Problem analysis procedures	Practice with feedback; introspection and condition-action rule development (see Doyle 1983; Frederiksen 1984; Scardamalia and Bereiter 1983). Use learning materials that provide written presentation of information, examples of solved problems, and directions requiring students to create condition-action rules for procedures that will need to be applied simultaneously (see Larkin 1980).
Problem-solving Strategies (see B.F. Anderson 1980; Reed 1982)	
Problem-solving procedures for problems in occupational cluster area General problem-solving strategies for unstructured problem or problem outside specific occupational cluster for which little or no knowledge is known (e.g., goal setting; means-end analysis, hypothesize-and-test procedure; planning; verbalization of goals and strategies; use of analogies)	Practice with feedback; reflect upon condition-action rule development. Combine rule learning, discovery learning, and learning from reflection on thinking processes (see Doyle 1983; Frederiksen 1984; Scardamalia and Bereiter 1983).

educators in developing the cognitive concepts and methods needed to help students develop learning and problem-solving skills.

- Considering the special needs of vocational education students for literacy and general education components, model career development systems should be developed for high school and adult vocational education. Such models might integrate general educational development components, which include reading, writing, computation, and communication; interpersonal relationships; problem solving and decision making; and learning, self-monitoring, and motivation. They might also include technical training, cognitive assessment, and career counseling (See McCombs 1981-1982, 1984, and O'Neil 1979 for contributions to such models.)

- A cognitive and learning style assessment battery would be useful to students, curriculum planners, and instructors for assessment before, during, and after vocational programs.

- A plan for research in vocational education with a cognitive focus needs to be developed to answer critical curriculum and instruction questions.

Progress toward focusing on the cognitive in vocational education—on helping students think and learn as they solve vocational problems—rather than on the behavior of students as they do vocational tasks, will do much toward preparing students for the challenges of the workplace.

REFERENCES AND RELATED READINGS

Adler, M. J. *The Paideia Proposal*. New York: Macmillan Publishing Co., 1982.

American Home Economics Association. *Concepts and Generalizations: Their Place in High School Home Economics Curriculum Development*. Washington, DC: AHEA, 1967.

Anderson, B. F. *The Complete Thinker: A Handbook of Techniques for Creative and Critical Problem Solving*. Englewood Cliffs, NJ: Prentice Hall, 1980.

Anderson, J. R. "Acquisition of Cognitive Skill." *Psychological Review* 89, no. 4 (July 1982): 369-406. (ERIC No. EJ 270 567)

———. *Cognitive Psychology and Its Implications*. San Francisco: W. H. Freeman and Company, 1980.

Atwood, N. K., and Baker, B. "Cognitive Approaches to the Analysis of Technical Understanding." Paper presented at the annual meeting of the American Educational Research Association, New Orleans, Louisiana, April, 1984.

Ausburn, F. B. *Impact of Learning Styles on Air Force Technical Training: Multiple and Linear Imagery in the Presentation of a Comparative Visual Location Task to Visual and Haptic Subjects*. Norman: College of Education, University of Oklahoma, 1979. (ERIC Document Reproduction Service No. ED 174 760)

Ausburn, L. J. *Impact of Learning Styles on Air Force Technical Training: Relationships among Cognitive Style Factors and Perceptual Types*. Norman: College of Education, University of Oklahoma, 1979. (ERIC Document Reproduction Service No. ED 174 761)

Ausubel, D. P; Novak, J. D.; and Hanesian, H. *Educational Psychology: A Cognitive View*. 2d ed. New York: Holt, Rinehart and Winston, 1978.

Baird, J. R., and White, R. T. "Promoting Self-Control of Learning." *Instructional Science* 11, no. 3 (December 1982): 227-247. (ERIC No. EJ 278 300)

Barbe, W., and Swassing, R. *Teaching through Modality Strengths: Concepts and Practices*. Columbus, OH: Zaner-Bloser, 1979.

Belmont, J. M.; Butterfield, E. C.; and Ferretti, R. P. "To Secure Transfer of Training Instruct Self-Management Skills." In *How and How Much Can Intelligence Be Increased*, edited by D. K. Detterman and R. J. Sternberg. Norwood, NJ: Ablex Publishing, 1982.

Bereiter, C. "How to Keep Thinking Skills from Going the Way of All Frills." *Educational Leadership* 42 (September 1984): 75-77.

Beyer, B. K. "Improving Thinking Skills—Defining the Problem." *Phi Delta Kappan* 65 (March 1984): 486-490. (ERIC No. EJ 294 947)

Beyth-Marom, R., and Dekel, S. "A Curriculum to Improve Thinking under Uncertainty." *Instructional Science* 12, no. 1 (April 1983): 67-82. (ERIC No. EJ 281 398)

Bhaskar, R.; Dillard, J. F.; and Stephens, R. G. "Skill Acquisition in the Bookkeeping Task." *Instructional Science* 11 (1983): 329-356.

Bhaskar, R.; Herstein, J. A.; and Hayes, J. R. "How to Decide How to Decide." *Instructional Science* 12 (1983): 267-277.

Biggs, J. B. "Learning Strategies, Student Motivation Patterns, and Subjectively Perceived Success." In *Cognitive Strategies and Educational Performance*, edited by J. R. Kirby. Orlando, FL: Academic Press, 1984.

Biggs, J. B., and Rihn, B. A. "The Effects of Intervention on Deep and Surface Approaches to Learning." In *Cognitive Strategies and Educational Performance*, edited by J. R. Kirby. Orlando, FL: Academic Press, 1984.

Bloom, B. S. "The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-one Tutoring." *Educational Researcher* 13, no. 6 (June-July 1984): 4-16. (ERIC No. EJ 303 699)

Bloom, B. S., and Broder, L. J. *Problem-solving Processes of College Students*. Chicago: University of Chicago Press, 1950.

Bottoms, G. "No Quick Fix Can Lead to Excellence." *VocEd* 58, no. 2 (March 1983): 10-11.

Bottoms, G., and Copa, P. "A Perspective on Vocational Education Today." *Phi Delta Kappan* 64, no. 5 (January 1983): 348-354. (ERIC No. EJ 276 275)

Bourne, L. E.; Dominowski, R. L.; and Loftis, E. F. *Cognitive Processes*. Englewood Cliffs, NJ: Prentice-Hall, 1979.

Bower, G. H., and Clark, M. C. "Narrative Stores as Mediators for Serial Learning." *Psychonomic Science* 14, no. 4 (1969): 181-182.

Bransford, J. D. *Human Cognition: Learning, Understanding and Remembering*. Belmont, CA: Wadsworth Publishing Co., 1979.

Bransford, J. D., and Johnson, M. K. "Contextual Prerequisites for Understanding: Some Investigations of Comprehension and Recall." *Journal of Verbal Learning and Verbal Behavior* 11 (December 1972): 717-726. (ERIC No. EJ 068 571)

Bransford, J. D.; Stein, B. S.; Vye, N. J.; Franks, J. J.; Auble, P. M.; Mezynski, K. J.; and Perfetto, G. A. "Differences in Approaches to Learning: An Overview." *Journal of Experimental Psychology: General* 111 (1982): 390-398.

Braune, R., and Foshay, W. R. "Towards a Practical Model of Cognitive/Information Processing Task Analysis and Schema Acquisition for Complex Problem-Solving Situations." *Instructional Science* 12, no. 2 (July 1983): 121-145. (ERIC No. EJ 287 002)

Brickell, H. M. "How Can We Teach Abstractions to Nonintellectual Students?" *Educational Leadership* 41, no. 4 (1983-1984): 64-65.

Bronfenbrenner, U. "Is Early Intervention Effective?" In *Handbook of Evaluation Research*, vol. 2, edited by E. L. Struening and M. Guttentag. Beverly Hills, CA: Sage, 1975.

Brown, A. L. "Knowing When, Where, and How to Remember: A Problem of Megacognition." In *Advances in Instructional Psychology*, vol. 1, edited by R. Glaser. Hillsdale, NJ: Lawrence Erlbaum Associates, 1978.

Brown, A. L., and Campione, J. C. "Modifying Intelligence or Modifying Cognitive Skills: More Than a Semantic Quibble?" In *How and How Much Can Intelligence Be Increased*, edited by D. K. Detterman and R. J. Sternberg. Norwood, NJ: Ablex Publishing, 1982.

Brown, A. L.; Campione, J. C.; and Day, J. D. "Learning to Learn: On Training Students to Learn from Texts." *Educational Researcher* 10, no. 2 (February 1981): 14-21. (ERIC No. EJ 241 605)

Brown, J. S., and Burton, R. B. "Diagnostic Models for Procedural Bugs in Basic Mathematical Skills." *Cognitive Science* 2 (1978): 155-192.

Brown, M., and Paolucci, B. *Home Economics: A Definition*. Washington, DC: American Home Economics Association, 1979.

Bruner, J. S. *The Process of Education*. New York: Random House, 1963.

Bruner, J. S.; Goodnow, J. J.; and Austin, G. A. *A Study of Thinking*. New York: Science Editions, 1963.

Burns, R. B., and Gallini, J. K. "The Relation of Cognitive and Affective Measures to Achievement during an Instructional Sequence." *Instructional Science* 12 (July 1983): 103-120. (ERIC No. EJ 287 001)

Calfee, R. "Cognitive Psychology and Educational Practice." In *Review of Research in Education*, edited by D. C. Berliner. Washington, DC: American Educational Research Association, 1981. Copyright 1981, American Educational Research Association, Washington, DC.

Calhoun, C. C., and Finch, A. V. *Vocational Education: Concepts and Operations*. 2d ed. Belmont, CA: Wadsworth Publishing Company, 1982.

Canelos, J. "The Function of Imagery Mental Representations of Perceptual Information as the Cognitive Basis of Applied Learning Strategies." *Journal of Instructional Psychology* 9 (1982): 3-12.

Carlisle, K. E. "The Process of Task Analysis." *Journal of Instructional Development* 6, no. 4 (1983): 31-35. (ERIC No. EJ 291 934)

Carroll, J. B., and Maxwell, S. E. "Individual Differences in Cognitive Abilities." *Annual Review of Psychology* 30 (1979): 603-40.

Case, R., and Bereiter, C. "From Behaviourism to Cognitive Behaviourism to Cognitive Development: Steps in the Evolution of Instructional Design." *Instructional Science* 13 (1984): 141-158.

Cazden, C. B. "Implications for Instructional Research." In *Cognition and Instruction*, edited by D. Klahr. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976.

Chall, J. S., and Mirsky, A. F. *Education and the Brain*. Part 2 of the Seventy-seventh Yearbook of the National Society for the Study of Education. Chicago: The University of Chicago Press, 1978.

Champagne, A. B.; Klopfer, L. E.; and Gunstone, R. F. "Cognitive Research and the Design of Science Instruction." *Educational Psychologist* 17 (1982): 31-53.

Chase, W. G., and Chi, M. T. H. "Cognitive Skill: Implications for Spatial Skill in Large-scale Environments." In *Cognition, Social Behavior, and the Environment*, edited by J. Harvey. Hillsdale, NJ: Lawrence Erlbaum Associates, 1981.

Collins, A. "Education and Understanding." In *Cognition and Instruction*, edited by D. Klahr. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976.

Cooper, J., and Croyle, R. T. "Attitudes and Attitude Change." *Annual Review of Psychology* 35 (1984): 395-426.

Corno, L. "Cognitive Organizing in Classroom." *Curriculum Inquiry* 11, no. 4 (Winter 1981): 359-377.

Corno, L., and Mandinach, E. B. "The Role of Cognitive Engagement in Classroom Learning and Motivation." *Educational Psychologist* 18 (1983): 88-108.

Costa, A. L. "Teaching for Intelligent Behavior." *Educational Leadership* 39, no. 1 (October 1981): 29-31. (ERIC No. EJ 253 751)

Craik, F. I. M., and Lockhart, R. S. "Levels of Processing: A Framework for Memory Research." *Journal of Verbal Learning and Verbal Behavior* 11, no. 6 (1972): 671-684.

Craik, F. I. M., and Tulving, E. "Depth of Processing and Retention of Words in Episodic Memory." *Journal of Experimental Psychology: General* 104 no. 3 (September 1975): 268-294. (ERIC No. EJ 128 798)

Curtis, M. E., and Glaser, R. "Changing Conceptions of Intelligence." *Review of Research in Education* 9 (1981): 111-148.

Cyert, R. M. "Problem Solving and Educational Policy." In *Problem Solving and Education*, edited by D. T. Tuma and F. Reif. Hillsdale, NJ: Lawrence Erlbaum Associates, 1980.

Dansereau, D. F. "The Development of a Learning Strategies Curriculum." In *Learning Strategies*, edited by H. F. O'Neil, Jr. New York: Academic Press, 1978.

Dansereau, D. F.; McDonald, B. A.; Collins, K. W.; Garland, J.; Holley, C. D.; Diekhoff, G. M.; and Evans, S. H. "Evaluation of a Learning Strategy System." In *Cognitive and Affective Learning Strategies*, edited by H. F. O'Neil, Jr. and C. D. Spielberger. New York: Academic Press, 1979.

Das, J. P. "Aspects of Planning." In *Cognitive Strategies and Educational Performance*, edited by J. R. Kirby. Orlando: Academic Press, 1984a.

———. "Intelligence and Information Integration." In *Cognitive Strategies and Educational Performance*, edited by J. R. Kirby. Orlando, FL: Academic Press, 1984b.

Das, J. P.; Kirby, J. R.; and Jarman, R. F. "Simultaneous and Successive Synthesis: An Alternative Model." *Psychological Bulletin* 82 (1975): 87-103.

Day, M. C. "Thinking at Piaget's Stage of Formal Operations." *Educational Leadership* 39, no. 1 (October 1981): 44-45. (ERIC No. EJ 253 754)

deCharms, R. *Enhancing Motivation: A Change in the Classroom*. New York: Irvington, 1976.

———. "Personal Causation Training in the Schools." *Journal of Applied Psychology* 2 (1972): 95-113.

DeLeeuw, L. "Teaching Problem Solving: An ATI Study of the Effects of Teaching Algorithmic and Heuristic Solution Methods." *Instructional Science* 12, no. 1 (April 1983): 1-48. (ERIC No. EJ 281 396)

Detterman, D. K., and Sternberg, R. J., eds. *How and How Much Can Intelligence Be Increased*. Norwood, NJ: Ablex Publishing, 1982.

Dillard, J. F.; Bhaskar, R.; and Stevens, R. G. "Using First Order Cognitive Analysis to Understand Problem Solving Behavior: An Example from Accounting." *Instructional Science* 11 (May 1982): 71-92. (ERIC No. EJ 263 479)

Dobrovolny, J. L. "Transitioning Learning Strategies Research into Practice. Focus on the Technical Training Instructor as a Learning Strategies Expert." *Journal of Instructional Development* 5 (Winter 1981-82): 17-23. (ERIC No. EJ 261 902)

Doyle, W. "Academic Work." *Review of Educational Research* 53, no. 2 (Summer 1983): 159-199. (ERIC No. EJ 284 879)

Dunn, R., and DeBello, T. "Learning Style Researchers Define Differences Differently." *Educational Leadership* 38, no. 5 (February 1981): 372-375. (ERIC No. EJ 242 309)

Dunn, R., and Dunn, K. *Teaching Students through Their Individual Learning Styles*. Reston, VA: Reston Publishing Company, 1978.

Education Commission of the States. *Action for Excellence*. Denver, CO: Task Force on Education for Economic Growth, Education Commission of the States, 1983. (ERIC Document Reproduction Service No. ED 235 588)

———. *Action in the States*. Denver, CO: Task Force on Education for Economic Growth, Education Commission of the States, 1984.

Ehrenberg, S. D. "Concept Learning: How to Make It Happen in the Classroom." *Educational Leadership* 39, no. 1 (October 1981): 36-43. (ERIC No. EJ 253 753)

Eisner, E. *Cognition and Curriculum*. New York: Longman, 1982.

———. *The Educational Imagination*. New York: Macmillan Publishing Company, 1979.

English, F. W., ed. *Fundamental Curriculum Decisions*. Alexandria, VA: Association for Supervision and Curriculum Development, 1983. (ERIC Document Reproduction Service No. ED 225 948)

Erickson, J. R., and Jones, M. R. "Thinking." *Annual Review of Psychology* 29 (1978): 61-90.

Estes, W. K. "Intelligence and Cognitive Psychology." In *The Nature of Intelligence*, edited by L. B. Resnick. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976.

Evans, R. P. *Foundations of Vocational Education*. Columbus, OH: Charles E. Merrill Publishing Company, 1971.

Farnham-Diggory, S. *Cognitive Processes in Education*. New York: Harper and Row, 1972.

———. "Toward a Theory of Instructional Growth." In *Cognition and Instruction*, edited by D. Klahr. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976.

Feuerstein, R.; Rand, Y.; Hoffman, M. G.; and Miller, R. *Instrumental Enrichment: An Intervention Program for Cognitive Modifiability*. Baltimore: University Park Press, 1980.

Fiske, S. T., and Taylor, S. E. *Social Cognition*. Reading, MA: Addison-Wesley Publishing Company, 1984.

Flavell, J. H. "Metacognitive Aspects of Problem Solving." In *The Nature of Intelligence*, edited by L. B. Resnick. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976.

Floden, R. E. "The Logic of Information-processing Psychology in Education." *Review of Research in Education* 9 (1981): 75-109.

Foshay, W. R. "Alternative Methods of Task Analysis." *Journal of Instructional Development* 6, no. 4 (1983): 2-9. (ERIC No. EJ 291 930)

Frederiksen, N. "Implications of Cognitive Theory for Instruction in Problem Solving." *Review of Educational Research* 54, no. 3 (1984): 363-407.

Gagne, R. M. *The Conditions of Learning*. 3d ed. New York: Holt, Rinehart and Winston, 1977.

———. "Learning Outcomes and Their Effects." *American Psychologist* 39, no. 4 (April 1984): 377-385. (ERIC No. EJ 297 600)

Gagne, R., and Briggs, L. *Principles of Instructional Design*. New York: Holt, Rinehart and Winston, 1974.

Galambos, E. C. *Issues in Vocational Education*. Atlanta, GA: Southern Regional Education Board, 1984. (ERIC Document Reproduction Service No. ED 240 312)

Gick, M. L., and Holyoak, K. J. "Schema Induction and Analogical Transfer." *Cognitive Psychology* 15 (1983): 1-38.

Giroux, H. A.; Penna, A. N.; and Pinar, W. F. *Alternatives in Education: Curriculum and Instruction*. Berkeley, CA: McCutchan Publishing, 1981.

Gisi, L. G., and Forbes, R. H. *The Information Society: Are High School Graduates Ready?* Denver, CO: Education Commission of the States, 1982. (ERIC Document Reproduction Service No. ED 223 812)

Glaser, R. "Education and Thinking: The Role of Knowledge." *American Psychologist* 39, no. 2 (February 1984): 93-104. (ERIC No. EJ 294 309)

———. "The Processes of Intelligence and Education." In *The Nature of Intelligence*, edited by L. B. Resnick. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976.

Glaser, R., and Pellegrino, J. "Improving the Skills of Learning." In *How and How Much Can Intelligence Be Increased*, edited by D. K. Detterman and R. J. Sternberg. Norwood, NJ: Ablex Publishing, 1982.

Glass, A. L.; Holyoak, K. J.; and Santa, J. L. *Cognition*. Reading, MA: Addison-Wesley Publishing Company, 1979.

Glucksberg, S., and McCloskey, M. "Decisions about Ignorance: Knowing That You Don't Know." *Journal of Experimental Psychology: Human Learning and Memory* 7 (September 1981): 311-325. (ERIC No. EJ 253 109)

Greenan, J. P. "Identification and Validation of Generalizable Skills in Vocational Programs." *Journal of Vocational Education Research* 8, no. 3 (Summer 1983): 46-71. (ERIC No. EJ 290 953)

Greeno, J. G. "A Study of Problem Solving." In *Advances in Instructional Psychology*, vol. 1, edited by R. Glaser. Hillsdale, NJ: Lawrence Erlbaum Associates, 1978.

———. "Trends in the Theory of Knowledge for Problem Solving." In *Problem Solving and Education: Issues in Teaching and Research*, edited by D. T. Tuma and F. Reif. Hillsdale, NJ: Lawrence Erlbaum Associates, 1980.

Hall, L. K., and Day, J. D. "Intelligence and Cognitive Control as Predictors of Generalization of Learning." Paper presented at the annual meeting of the American Educational Research Association, New Orleans, Louisiana, April 1984.

Hall, R. "The Importance of Lifetime Jobs in the U.S. Economy." *American Economic Review* 72, no. 4 (September 1982): 716-724.

Hart, L. "The Three-Brain Concept and the Classroom." *Phi Delta Kappan* 62, no. 7 (March 1981): 504-506. (ERIC No. EJ 242 409)

Harvey, J. H., and Weary, G. "Current Issues in Attribution Theory and Research." *Annual Review of Psychology* 35 (1984): 427-459.

Hawk, P. P., and McLeod, N. P. "Graphic Organizers: A Cognitive Teaching Method That Works." *The Directive Teacher* 6 (Winter-Spring 1984): 6-7.

Hayes, J. R. "It's the Thought That Counts: New Approaches to Educational Theory." In *Cognition and Instruction*, edited by D. Klahr. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976.

Hewson, P. W., and Hewson, M. G. A. "The Role of Conceptual Conflict in Conceptual Change and the Design of Science Instruction." *Instructional Science* 13 (May 1984): 1-13. (ERIC No. EJ 301 700)

Hewson, P. W., and Posner, G. J. "The Use of Schema Theory in the Design of Instructional Materials: A Physics Example." *Instructional Science* 13 (1984): 119-139.

Hilgard, E. R. "Consciousness in Contemporary Psychology." *Annual Review of Psychology* 31 (1980): 1-26.

Hillyard, S. A., and Kutas, M. "Electrophysiology of Cognitive Processing." *Annual Review of Psychology* 34 (1983): 33-61.

Hobbs, N. "Feuerstein's Instrumental Enrichment: Teaching Intelligence to Adolescents." *Educational Leadership* 37, no. 7 (April 1980): 566-568. (ERIC No. EJ 221 533)

Hoffman, C. K., and Medsker, K. L. "Instructional Analysis: The Missing Link Between Task Analysis and Objectives." *Journal of Instructional Development* 6, no. 4 (1983): 17-23. (ERIC No. EJ 291 932)

Horton, D. L., and Mills, C. B. "Human Learning and Memory." *Annual Review of Psychology* 35 (1984): 361-394.

Horton, J. A., and Bailey, G. D. "Mental Rehearsal and Visual Literacy." *Journal of Instructional Psychology* 9 (1982): 202-213.

Hosseini, J., and Ferrell, W. R. "Detectability of Correctness: A Measure of Knowing That One Knows." *Instructional Science* 11 (1982): 113-127.

Houston, J. P. *Fundamentals of Learning and Memory*. 2d ed. New York: Academic Press, 1981.

Hunt, J. B., et al. "Action for Excellence: Excerpts from the Task Force Report." *Educational Leadership* 41 (September 1983): 14-18. (ERIC No. EJ 286 564)

Johnson-Laird, P. N., and Wason, P. C., eds. *Thinking: Readings in Cognitive Science*. Cambridge: Cambridge University Press, 1977.

Joyce, B., and Weil, M. *Models of Teaching*. 2d ed. Englewood Cliffs, NJ: Prentice-Hall, 1980.

Karat, J. "A Model of Problem Solving with Incomplete Constraint Knowledge." *Cognitive Psychology* 14 (1982): 538-559.

Keefe, J. W. "Learning Style: An Overview." In *Student Learning Styles*. Reston, VA: National Association of Secondary School Principals, 1979. (ERIC Document Reproduction Service No. ED 182 859)

———. In *Student Learning Styles and Brain Behavior*. Reston, VA: National Association of Secondary School Principals, 1982. (ERIC Document Reproduction Service No. ED 227 565)

Kennedy, P.; Esque, T.; and Novak, J. "A Functional Analysis of Task Analysis Procedures for Instructional Design." *Journal of Instructional Development* 6, no. 4 (1983): 10-16. (ERIC No. EJ 291 931)

Kimble, G. A. "Cognitive Psychology and Learning Strategies." In *Cognitive and Affective Learning Strategies*, edited by H. F. O'Neil, Jr. and C. D. Spielberger. New York: Academic Press, 1979.

Kirby, J. R., ed. *Cognitive Strategies and Educational Performance*. Orlando, FL: Academic Press, 1984.

Kirby, P. *Cognitive Style, Learning Style, and Transfer Skill Acquisition*. Information Series no. 195. Columbus: The National Center for Research in Vocational Education, The Ohio State University, 1979. (ERIC Document Reproduction Service No. ED 186 685)

Klahr, D. *Cognition and Instruction*. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976.

Klatzky, R. *Human Memory*. 2d ed. San Francisco: W. H. Freeman and Company, 1980.

Klemp, G., Jr. "Three Factors of Success." In *Relating Work and Education*, edited by D. W. Vermilye. San Francisco: Jossey-Bass Publishers, 1977.

Knaak, W. C. *Learning Styles: Applications in Voc Ed*. Information Series no. 254. Columbus: The National Center for Research in Vocational Education, The Ohio State University, 1983. (ERIC Document Reproduction Service No. ED 229 573)

———. "Research in Learning Styles." In *Education in the 80s: Vocational Education*, edited by N. K. Christian. Washington, DC: National Education Association, 1982. (ERIC Document Reproduction Service No. ED 212 827)

Kogan, N. "Educational Implications of Cognitive Styles." In *Psychology and Educational Practice*. Glenview, IL: Scott, Foresman, 1971.

Lachman, R.; Lachman, J.; and Butterfield, E. C. *Cognitive Psychology and Information Processing*. Hillsdale, NJ: Lawrence Erlbaum Associates, 1979.

Larkin, J. H. "Teaching Problem Solving in Physics: The Psychological Laboratory and the Practical Classroom." In *Problem Solving in Education*, edited by D. T. Tuma and F. Reif. New York: Lawrence Erlbaum Associates, 1980.

Laster, J. F. "A Practical Action Teaching Model." *Journal of Home Economics* 74 (Fall 1982): 41-44. (ERIC No. EJ 267 914)

———. "Facilitating Conceptual Change." *Distaff* 50 (Spring 1984): 14-15.

Laster, J. F., and Dohner, R., eds. *Vocational Home Economics Curriculum: State of the Art*. Bloomington, IL: McKnight Publishing Company, forthcoming.

Lawson, M. J. "Being Executive about Metacognition." In *Cognitive Strategies and Educational Performance*, edited by J. R. Kirby. Orlando, FL: Academic Press, 1984.

Levin, J. R. "What Have We Learned about Maximizing What Children Learn?" In *Cognitive Learning in Children: Theories and Strategies*, edited by J. R. Levin and V. L. Allen. New York: Academic Press, 1976.

Levin, T. "Instruction Which Enables Students to Develop Higher Mental Processes." *Evaluation in Education: An International Review Service* 3 (1979): 173-220.

Leyton, F. S. "The Extent to Which Group Instruction Supplemented by Mastery of the Initial Cognitive Prerequisites Approximates the Learning Effectiveness of One-to-One Tutorial Methods." Ph.D. diss., University of Chicago, 1983.

Linn, M. C. "The Importance of Cognitive Psychology in Curriculum Development and Teacher Education." Paper presented at the National Commission on Excellence in Education's site visit to Lawrence Hall of Science, University of California, Berkeley, March 1982. (ERIC Document Reproduction Service No. ED 231 625)

Lloyd, R. F., and Rehg, V. R. *Quality Circles: Applications in Vocational Education*. Information Series no. 249. Columbus: The National Center for Research in Vocational Education, The Ohio State University, 1983. (ERIC Document Reproduction Service No. ED 229 607)

Lochhead, J. "Research Synthesis on Problem Solving." *Educational Leadership* 39 (October 1981): 68-70. (ERIC No. EJ 253 759)

Lochhead, J., and Clement, J., eds. *Cognitive Process Instruction*. Philadelphia: Franklin Institute Press, 1979. (ERIC Document Reproduction Service No. ED 234 997)

Luiten, J.; Ames, W.; and Ackerson, G. "A Meta-analysis of the Effects of Advance Organizers on Learning and Retention." *American Educational Research Journal* 17, no. 2 (Summer 1980): 211-218. (ERIC No. EJ 233 231)

MacDonald-Ross, M. "Behavioural Objectives: A Critical Review." In *Curriculum Design*, edited by M. Golby, J. Greenwald, and R. West. New York: John Wiley and Sons, 1975.

Mansfield, R. S.; Busse, T. V.; and Krepelka, E. J. "The Effectiveness of Creativity Training." *Review of Educational Research* 48 (Fall 1978): 517-536. (ERIC No. EJ 200 558)

Martin, J. "Toward a Cognitive Schemata Theory of Self-Instruction." *Instructional Science* 13 (1984): 159-180.

Masters, J. C. "Developmental Psychology. *Annual Review of Psychology* 32 (1981): 117-51.

Mayer, R. E. *The Promise of Cognitive Psychology*. San Francisco: W. H. Freeman and Company, 1981.

———. *Thinking, Problem Solving, Cognition*. New York: W. H. Freeman and Company, 1983.

McCombs, B. L. "Metacognitive and Cognitive Components of Motivation: Teaching Self-Awareness and Self-Management via a Problem Solving Approach." Paper presented at the annual meeting of the American Educational Research Association, New Orleans, Louisiana, April 1984.

———. "Transitioning Learning Strategies Research into Practice: Focus on the Student in Technical Training." *Journal of Instructional Development* 5 (Winter 1981-82): 10-17. (ERIC No. EJ 261 901)

Medin, D. L., and Smith, E. E. "Concepts and Concept Formation." *Annual Review of Psychology* 35 (1984): 113-138.

———. "Strategies and Classification Learning." *Journal of Experimental Psychology: Human Learning and Memory* 7, no. 4 (July 1981): 241-253. (ERIC No. EJ 253 106)

Myers, J. L.; O'Brien, E. J.; Balota, D. A.; and Toyofuku, M. L. "Memory Search without Interference: The Role of Integration." *Cognitive Psychology* 16 (1984): 217-242.

National Academy of Sciences. *High Schools and the Changing Workplace*. Washington, DC: National Academy Press, 1984.

National Association of Secondary School Principals. *Student Learning Styles: Diagnosing and Prescribing Programs*. Reston, VA: National Association of Secondary School Principals, 1979. (ERIC Document Reproduction Service No. ED 182 859)

———. *Student Learning Styles and Brain Behavior: Programs, Instrumentation, Research*. Reston, VA: National Association of Secondary School Principals, 1982. (ERIC Document Reproduction Service No. ED 227 565)

National Commission on Excellence in Education. *A Nation at Risk*. Washington, DC: National Commission on Excellence in Education, 1983. (ERIC Document Reproduction Service No. ED 226 006)

Neisser, U. *Cognition and Reality*. San Francisco: W. H. Freeman and Company, 1976.

———. *Cognitive Psychology*. New York: Meredith Publishing Company, 1967.

Newell, A., and Simon, H. A. *Human Problem Solving*. Englewood Cliffs, NJ: Prentice-Hall, 1972.

Norman, D. A. "Cognitive Engineering and Education." In *Problem Solving and Education: Issues in Teaching and Learning*, edited by D. T. Tuma and F. Reif. Hillsdale, NJ: Lawrence Erlbaum Associates, 1980.

Norman, D. A., ed. *Perspectives on Cognitive Science*. Norwood, NJ: Ablex Publishing, 1981.

Norman, D. A.; Gentner, D. R.; and Stevens, A. L. "Comments on Learning Schemata and Memory Representation." In *Cognition and Instruction*, edited by D. Klahr. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976.

Olson, D. R. "Notes on a Cognitive View of Instruction. In *Cognition and Instruction*, edited by D. Klahr. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976.

O'Neil, H. F., Jr., ed. *Learning Strategies*. New York: Academic Press, 1978.

O'Neil, H. F., Jr., and Spielberger, C. D., eds. *Cognitive and Affective Learning Strategies*. New York: Academic Press, 1979.

Owie, I. "Locus of Control, Instructional Mode and Student's Achievement." *Instructional Science* 12, no. 4 (December 1983): 383-388. (ERIC No. EJ 292 001)

Pellegrino, J. W. "Analyzing Aptitudes for Learning: Inductive Reasoning." In *Advances in Instructional Psychology*, vol. 2, edited by R. Glaser. Hillsdale, NJ: Lawrence Erlbaum Associates, 1979.

Personick, V. A. "The Job Outlook through 1995: Industry Output and Employment Projections." *Monthly Labor Review* 106, no. 11 (November 1983): 24-36. (ERIC No. EJ 289 234)

Peterson, P. L.; Swing, S. R.; Stark, K. D.; and Waas, G. A. "Students' Cognitions and Time on Task during Mathematics Instruction." *American Educational Research Journal* 21, no. 3 (Fall 1984): 487-515. (ERIC No. EJ 303 670)

Pickthorne, B. "Error Factors: A Missing Link between Cognitive Science and Classroom Practice?" *Instructional Science* 11 (January 1983): 281-312. (ERIC No. EJ 276 748)

Pitts, R. B. "Development of a General Problem-solving Schema in Adolescence and Early Adulthood." *Journal of Experimental Psychology: General* 112 (1983): 547-584.

Pitz, G. F., and Sachs, N. J. "Judgment and Decision: Theory and Application." *Annual Review of Psychology* 35 (1984): 139-163.

Polya, G. *How to Solve It*. Princeton, NJ: Princeton University Press, 1945.

Posner, G. J. "Tools for Curriculum Research and Development: Potential Contributions from Cognitive Science." *Curriculum Inquiry* 8 (Winter 1978): 311-340. (ERIC No. EJ 199 417)

Posner, M. I. "Information Processing Models—In Search of Elementary Operations." *Annual Review of Psychology* 33 (1982): 477-514.

Posner, M., and Keele, S. W. "Skill Learning." In *Second Handbook of Research on Teaching*, edited by R. M. W. Travers. Chicago: Rand McNally and Company, 1973.

Pratzner, F. C., and Frymier, J. F. *The Roles and Functions of Vocational Education: Some Current Perspectives*. Columbus: The National Center for Research in Vocational Education, The Ohio State University, 1983. (ERIC Document Reproduction Service No. ED 227 308)

Rasmussen, J., and Jensen, A. "Mental Procedures in Real-Life Tasks: A Case Study of Electronic Trouble Shooting." *Ergonomics* 17 (1974): 293-307.

Reed, S. K. *Cognition: Theory and Application*. Monterey, CA: Brooks/Cole Publishing Co., 1982.

Reif, F., and Heller, J. I. "Knowledge Structure and Problem Solving in Physics." *Educational Psychologist* 17, no. 2 (1982): 102-127. (ERIC No. EJ 281 844)

Reigeluth, C. M. "Current Trends in Task Analysis." *Journal of Instructional Development* 6, no. 4 (1983a): 24-30, 35. (ERIC No. EJ 291 933)

———. "Meaningfulness and Instruction: Relating What Is Being Learned to What a Student Knows." *Instructional Science* 12, no. 3 (October 1983b): 197-218. (ERIC No. EJ 290 138)

Resnick, L. B., ed. "The Future of IQ Testing in Education." In *Human Intelligence: Perspectives on Its Theory and Measurement*, edited by R. J. Sternberg and D. K. Detterman. Norwood, NJ: Ablex Publishing Company, 1979.

———. "Instructional Psychology." *Annual Review of Psychology* 32 (1981): 659-704.

———. *The Nature of Intelligence*. Hillsdale, NJ: Lawrence Erlbaum Associates, 1976.

———. "Toward a Cognitive Theory of Instruction." In *Learning and Motivation in the Classroom*, edited by S. G. Paris, G. M. Olson, and H. W. Stevenson. Hillsdale, NJ: Lawrence Erlbaum Associates, 1983.

Ribich, F. D., and Schmeck, R. R. "Multivariate Relationships between Measures of Learning Style and Memory." *Journal of Research in Personality* 13, no. 4 (December 1979): 515-529. (ERIC No. EJ 213 701)

Rickards, J. P., and August, G. J. "Generative Underlining Strategies in Prose Recall." *Journal of Educational Psychology* 67 (December 1975): 860-865. (ERIC No. EJ 133 653)

Rigney, J. W. "Cognitive Learning Strategies and Qualities in Information Processing." In *Aptitude, Learning, and Instruction*, vol. 1, edited by R. Snow, P. Federico, and W. Montague. Hillsdale, NJ: Lawrence Erlbaum Associates, 1980.

———. "Learning Strategies: A Theoretical Perspective." In *Learning Strategies*, edited by H. F. O'Neil, Jr. New York: Academic Press, 1978.

Roberts, F. C., and Park, O. "Feedback Strategies and Cognitive Style in Computer-based Instruction." *Journal of Instructional Psychology* 11 (1984): 63-74.

Roberts, T. B. "Consciousness, Psychology, and Education." *Journal of the Society for Accelerative Teaching and Learning* 5 (1980): 189-232.

Roberts, T. B., and Clark, F. *Transpersonal Psychology in Education*. Fastback Pamphlet no. 53. Bloomington, IN: Phi Delta Kappa Educational Foundation, 1975. (ERIC Document Reproduction Service No. ED 107 626)

Ross, B. H. "Remindings and Their Effects in Learning a Cognitive Skill." *Cognitive Psychology* 16 (July 1984): 371-416. (ERIC No. EJ 302 163)

Rutherford, R. B., Jr.; Howell, K. W.; and Rueda, R. "Self-Control Instruction for Behavior Disordered Students: Design and Implementation." *Journal of Instructional Psychology* 9 (1982): 91-99.

Saylor, J. G.; Alexander, W. M.; and Lewis, A. J. *Curriculum Planning for Better Teaching and Learning*, 4th ed. New York: Holt, Rinehart and Winston, 1981.

Scardamalia, M., and Bereiter, C. "Child as Co-investigator: Helping Children Gain Insight into Their Own Mental Processes." In *Learning and Motivation in the Classroom*, edited by S. G. Paris, G. M. Olson, H. W. Stevenson. Hillsdale, NJ: Lawrence Erlbaum Associates, 1983.

Schmeck, R. R. "Improving Learning by Improving Thinking." *Educational Leadership* 38 (February 1981): 384-385. (ERIC No. EJ 242 313)

———. "Relationships between Measures of Learning Style and Reading Comprehension." *Perceptual and Motor Skills* 50, no. 2 (April 1980): 461-462.

Schmeck, R. R., and Grove, E. "Academic Achievement and Individual Differences in Learning Process." *Applied Psychological Measurement* 3, no. 1 (Winter 1979): 43-49. (ERIC No. EJ 207 265)

Schmeck, R. R., and Ribich, F. D. "Construct Validation of the Inventory of Learning Processes." *Applied Psychological Measurement* 2, no. 4 (Fall 1979): 551-562. (ERIC No. EJ 207 255)

Schmeck, R. R.; Ribich, F.; and Ramanaiah, N. "Development of a Self-Report Inventory for Assessing Individual Differences in Learning Processes." *Applied Psychological Measurement* 1 (Summer 1977): 413-431. (ERIC No. EJ 186 180)

Schneider, W., and Shiffrin, R. M. "Controlled and Automatic Human Information Processing: I. Detection, Search, and Attention." *Psychological Review* 84 (January 1977): 1-66. (ERIC No. EJ 159 781)

Schoenfeld, A. H. "Can Heuristics Be Taught?" In *Cognitive Process Instruction*, edited by J. Lochhead and J. Clement. Philadelphia: The Franklin Institute Press, 1979. (ERIC Document Reproduction Service No. ED 234 997)

Schroder, H. M.; Driver, M. J.; and Streufert, S. *Human Information Processing*. New York: Holt, Rinehart and Winston, 1967.

Schroder, H. M.; Karlins, M.; and Phares, J. O. *Education for Freedom*. New York: John Wiley and Sons, 1973.

Schwab, J. J. "Structure of the Disciplines: Meanings and Significances." In *Curriculum Design*, edited by M. Golby, J. Greenwald and R. West. New York: John Wiley and Sons, 1975.

Shaw, M. L. "Attending to Multiple Sources of Information: The Integration of Information in Decision Making." *Cognitive Psychology* 14 (1982): 353-409.

Shiffrin, R. M., and Atkinson, R. C. "Storage and Retrieval Processes in Long-term Memory." *Psychological Review* 76, no. 2 (1969): 179-193.

Shiffrin, R. M., and Schneider, W. "Controlled and Automatic Human Information Processing: II. Perceptual Learning, Automatic Attending, and a General Theory." *Psychological Review* 84 (March 1977): 127-190. (ERIC No. EJ 161 631)

Shvell, T. J. "Developing a Viable Link between Scientific Psychology and Educational Practices." *Instructional Science* 11 (1982): 155-167.

Simon, H. A. "Information Processing Models of Cognition." *Annual Review of Psychology* 30 (1979): 363-396.

———. "Problem Solving and Education." In *Problem Solving and Education*, edited by D. T. Tuma and F. Reif. Hillsdale, NJ: Lawrence Erlbaum Associates, 1980.

———. *The Sciences of the Artificial*. 2d ed. Cambridge, MA: MIT Press, 1981.

Singer, R. N. "To Err Or Not to Err: A Question for the Instruction of Psychomotor Skills." *Review of Educational Research* 47 (Summer 1977): 479-498. (ERIC No. EJ 172 815)

———. *Motor Learning and Human Performance*. 3d ed. New York: Macmillan Publishing Company, 1980.

Singer, R. N., and Gerson, R. F. "Learning Strategies, Cognitive Processes, and Motor Learning." In *Cognitive and Affective Learning Strategies*, edited by H. F. O'Neil, Jr., and C. D. Spielberger. New York: Academic Press, 1979.

Sizer, T. R. *Horace's Compromise: The Dilemma of the American High School*. Boston: Houghton Mifflin Company, 1984.

Snelbecker, G. E. "Instructional Theory Alive and Well?" In *Instructional-Design Theories and Models: An Overview of Their Current Status*, edited by C. M. Reigeluth. Hillsdale, NJ: Lawrence Erlbaum Associates, 1983.

Sowa, C. J., and Burks, H. M. "Comparison of Cognitive Restructuring and Contingency-based Instructional Models for Alleviation of Learned Helplessness." *Journal of Instructional Psychology* 10 (1983): 186-191.

Sprinthall, N. A. "Psychology for Secondary Schools: The Saber-Tooth Curriculum Revisited?" *American Psychologist* 35, no. 4 (April 1980): 336-347. (ERIC No. EJ 224 652)

Stein, B. S.; Bransford, J. D.; Franks, J. J.; Owings, R. A.; Vye, N. J.; and McGraw, W. "Differences in the Precision of Self-Generated Elaborations." *Journal of Experimental Psychology: General* 111 (1982): 399-405.

Stein, B. S.; Bransford, J. D.; Franks, J. J.; Vye, N. J.; and Perfetto, G. A. "Differences in Judgments of Learning Difficulty." *Journal of Experimental Psychology: General* 111 (1982): 406-413.

Sternberg, R. J. "Criteria for Intellectual Skills Training." *Educational Researcher* 12 (February 1983): 6-12, 26. (ERIC No. EJ 275 658)

———. "How Can We Teach Intelligence?" *Educational Leadership* 42 (September 1984): 38-48.

Sternberg, R. J.; Ketron, J. L.; and Powell, J. S. "Componential Approaches to the Training of Intelligent Performance." In *How and How Much Can Intelligence Be Increased*, edited by D. K. Detterman and R. J. Sternberg. Norwood, NJ: Ablex Publishing, 1982.

Stevens, R. G.; Bhaskar, R.; and Dillard, J. R. "The Role of Task Analysis in Understanding Problem-solving Behavior." *Instructional Science* 10 (April 1981): 23-45. (ERIC No. EJ 248 901)

Sticht, T. G. "Developing Literacy and Learning Strategies in Organizational Settings." In *Cognitive and Affective Learning Strategies*, edited by H. F. O'Neil, Jr., and C. D. Spielberger. New York: Academic Press, 1979.

Tennyson, R. D., and Park, O. "The Teaching of Concepts, A Review of Instructional Design Research Literature." *Review of Educational Research* 50, no. 1 (Spring 1980): 55-70. (ERIC No. EJ 224 596)

Thomas, R. M. "Mapping Meta-Territory." *Educational Researcher* 13, no. 1 (January 1984): 16-18. (ERIC No. EJ 294 315)

Tillema, H. "Webteaching: Sequencing of Subject Matter in Relation to Prior Knowledge of Pupils." *Instructional Science* 12 (December 1983): 321-332. (ERIC No. EJ 291 995)

Torrance, E. P. "Can We Teach Children to Think Creatively?" *Journal of Creative Behavior* 6 (1972): 114-143.

Travers, R. M. W. *Essentials of Learning: The New Cognitive Learning for Students of Education*. 5th ed. New York: Macmillan Publishing Company, 1982.

Tuma, D. T., and Reif, F., ed. *Problem Solving and Education: Issues in Teaching and Research*. Hillsdale, NJ: Lawrence Erlbaum Associates,1980.

Tyler, L. E. *Individual Differences*. New York: Appleton-Century-Crofts, 1974.

———. *Individuality*. San Francisco: Jossey-Bass Publishers, 1978.

———. "More Stately Mansions—Psychology Extends Its Bounds." *Annual Review of Psychology* 32 (1981): 1-20.

Vye, N. J., and Bransford, J. D. "Programs for Teaching Thinking." *Educational Leadership* 39, no. 1 (October 1981): 26-28. (ERIC No. EJ 253 750)

Wagner, R. K., and Sternberg, R. J. "Alternative Conceptions of Intelligence and Their Implications for Education." *Review of Educational Research* 54 (Summer 1984): 179-223.

Watkins, D. "Depth of Processing and the Quality of Learning Outcomes." *Instructional Science* 12 (1983): 49-58.

Weinstein, C. E. "Elaboration Skills as a Learning Strategy." In *Learning Strategies*, edited by H. F. O'Neil, Jr. New York: Academic Press, 1978.

Weisberg, A. "What Research Has to Say About Vocational Education and the High Schools." *Phi Delta Kappan* 64, no. 5 (January 1983): 355-359. (ERIC No. EJ 276 276)

Whimbey, A. "The Key to Higher Order Thinking is Precise Processing." *Educational Leadership* 42 (September 1984): 66-70.

———. "Students Can Learn to Be Better Problem Solvers." *Educational Leadership* 37 (April 1980): 560-563, 565. (ERIC No. EJ 221 531)

Whimbey, A., and Lochhead, J. *Problem Solving and Comprehension: A Short Course in Analytical Reasoning*, 3d ed. Philadelphia: Franklin Institute Press, 1982.

Whimbey, A., and Whimbey, L. S. *Intelligence Can Be Taught*. New York: Bantam Books, 1975.

Wickelgren, W. A. *How to Solve Problems*. San Francisco: W. H. Freeman and Company, 1974.

———. "Human Learning and Memory." *Annual Review of Psychology* 32 (1981): 21-52.

Wildman, T. M. "Cognitive Theory and the Design of Instruction." *Educational Technology* 21, no. 7 (July 1981): 14-20. (ERIC No. EJ 248 993)

Willems, J. "Problem-based (Group) Teaching: A Cognitive Science Approach to Using Available Knowledge." *Instructional Science* 10 (April 1981): 5-21. (ERIC No. EJ 248 900)

Witkin, H. A. "Cognitive Style in Academic Performance and in Teacher-Student Relations." In *Individuality in Learning*, edited by S. Messick and associates. San Francisco: Jossey-Bass Publishers, 1976.

Wittrock, M. C. "Applications of Cognitive Psychology to Education and Training." In *Cognition and Affective Learning Strategies*, edited by H. F. O'Neil, Jr. and C. D. Spielberger. New York: Academic Press, 1979a.

———, ed. *The Brain and Psychology*. New York: Academic Press, 1980.

———. "The Cognitive Movement in Instruction." *Educational Researcher* 8 (February 1979b): 5-11. (ERIC No. EJ 197 331)

———. "Education and the Cognitive Process of the Brain." In *Education and the Brain*, edited by J. S. Chall and A. F. Mirsky. Chicago: University of Chicago Press, 1978.

———. "Educational Implications of Recent Brain Research." *Educational Leadership* 39, no. 1 (October 1981a): 12-15. (ERIC No. EJ 253 747)

———. "Instructional Psychology." *Annual Review of Psychology* 28 (1977): 417-459.

———. "Learning as a Generative Process." *Educational Psychologist* 11 (1974): 87-95.

———. "Reading Comprehension." In *Neuropsychological and Cognitive Processes in Reading*, edited by F. J. Pirozzolo and M. C. Wittrock. New York: Academic Press, 1981b.

Wittrock, M. C., and Lumsdaine, A. A. "Instructional Psychology." *Annual Review of Psychology* 28 (1977): 417-459.

Zsohar, H.; Hegstad, L. N.; Sullivan, H. J.; and Hug, A. C. "Incorporating Experimental Research into the Instructional Development Process." *Journal of Instructional Development* 5 (Fall 1981): 30-34. (ERIC No. EJ 255 203)

TO ORDER ADDITIONAL COPIES OF THIS PUBLICATION, USE—	ORDER NUMBER	PRICE
• *Toward Excellence in Secondary Vocational Education: Using Cognitive Psychology in Curriculum Planning*	IN 297	$7.25

TO ORDER RELATED PUBLICATIONS, REFER TO—		
• *Toward Excellence in Secondary Vocational Education: Elements of Program Quality*	IN 291	$4.75
• *Toward Excellence in Secondary Vocational Education: Implementing Standards*	IN 292	$4.25
• *Toward Excellence in Secondary Vocational Education: Improving Teaching*	IN 293	$4.75
• *Toward Excellence in Secondary Vocational Education: Using Evaluation Results*	IN 294	$4.75
• *Toward Excellence in Secondary Vocational Education: Developing Pretechnical Curricula*	IN 295	$5.50
• *Toward Excellence in Secondary Vocational Education: Providing Job Training*	IN 296	$4.75
• *The Unfinished Agenda: The Role of Vocational Education in the High School*	IN 289	$4.75

ORDERING INSTRUCTIONS

To order additional copies, please use order number and title. Orders of $10.00 or less should be prepaid. Make remittance payable to the National Center for Research in Vocational Education. Mail order to:

The National Center for Research
in Vocational Education
National Center Publications, Box F
1960 Kenny Road
Columbus, Ohio 43210–1090

Prices listed are in effect at the time of publication of this book. All prices include postage and handling. Prices are subject to change without notice.

Quantity Discounts
Orders of five (5) or more items, as listed by publication number and title, with a total dollar value for the order of:

$ 50 to $100, the discount is 5%
$101 to $200, the discount is 10%
$201 to $300, the discount is 15%
$301 to $400, the discount is 20%
$401 and above, the discount is 25%

International Orders
All orders, in any amount, from outside the United States and its possessions are to be paid in U.S. currency. Additional postage and handling charges may be added for foreign shipments if necessary.